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SIXTH EDITION. TWENTIETH THOUSAND.

A

ONVERSATION ON MINES, &c.,

BETWEEN

A FATHER AND SON;

TO WHICH ARE ADDED

QUESTIONS AND ANSWERS TO ASSIST CANDIDATES
TO OBTAIN CERTIFICATES FOR THE
MANAGEMENT OF COLLIERIES,
A LECTURE ON THE ATMOSPHERE—ITS CHANGES
AND EXPLOSIVE GASES,
ABLES OF CALCULATIONS, RULES OF MEASUREMENTS,
ETC., ETC.

BY

WILLIAM HOPTON,

CERTIFICATED COLLIERY MANAGER,

Author of "The Lundhill Mode of Ventilation," "A Practical Treatise on Gases, Explosions, Ventilation, and the Workings of Mines," and a successful competitor for Mr. Hermon's Prize for the best suggestions for the "Prevention" of Catastrophes in Mines; Etc., etc.

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PREFACE TO THE SIXTH EDITION.

In the pages of this work, a clear explanation of every subject on mining is given; the object is to assist persons in the better management and conducting of mines.

The following subjects are clearly and intelligibly explained: how mines generate gases; why the discharge is greater in one mine than another, and how others discharge a mixture of gases; how the weather on the surface of the earth affects the workings of a mine; the power of explosions, and how to diminish it; several ways of ventilating mines, and how currents of air are propelled around the workings; the friction of the ventilating currents, and how to diminish it; with several ways of working out coal, &c., &c.; together with numerous questions and answers on mining matters to assist applicants intending to pass the examination as mine managers, and to assist them in the discharge of their duties.

The great and continued demand for this book is a sufficient proof of its great value to the mining population. Twenty thousand copies have now been circulated, and the book has found its way into every part of the mining world where the English language is spoken.

St. Helens, 1875.

PREFACE TO THE FIFTH EDITION.

IN the space of a few months the fourth edition of the Conversation on Mines between Father and Son, has been sold; and the fifth edition, completing Fifteen Thousand Copies, is now printed.

St. Helens, 1873.

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PREFACE TO THE FOURTH EDITION.

THE fourth edition is improved with tables of calculations, rules of measurements, and much information on mines added.

The work is a useful companion to all engaged in mining, and it will recommend itself to every person if only perused. The Conversation on Mines between Father and Son has become a household word in every colliery and mining district; and no work on mining was ever so successful as it, ten thousand copies being now circulated.

St. Helens, 1873.

PREFACE TO THE THIRD EDITION.

HOPTON'S Conversations on Mines between a Father and Son is again sold off, and large orders are daily sent in from every mining district in the British Islands, and also from America.

It is from request that the Author publishes this Third Edition of his work, the demand for the same being so great.

When Mr. Hopton wrote the work it was not with the intention, neither did he ever expect it to have been published in the form and style it now appears, but only in articles suitable for public newspapers; and not before eleven hundred copies were ordered did he consent, after much request, to have it published as it now appears.

At the age of seven years Mr. Hopton laboured in mines, and at twenty-one years of age he was engaged to take charge of the underground workings. His son, also, is underground viewer under him, and the son of a "colliery proprietor" is also with him, learning the duties of mine management, so that he, Mr. Hopton, knowing what young men require, is well able to supply their need, having had long experience in mining.

The value of the work may be known by its great demand, and among those who have purchased it, many speak of its value.

December, 1867.

PREFACE TO THE SECOND EDITION.

This work, Conversations on Mines between a Father and Son, is now being circulated in every mining district in the British Islands, also in some of the mining districts in America, and other foreign countries; and as the author has orders on hand for several hundreds of copies, he is induced to publish this second edition, the first edition being sold off in a very short time.

The work was written for the better information of under-lookers, deputies, firemen, and miners, as it is well known that the generality of them are ignorant of that information respecting mines which they ought to have.

To make the work efficient and complete, for the information of those for whom it was written, the author has spared neither time nor expense.

A great number of testimonials to the work have been received from colliery masters and managers, many of them having supplied copies to their officials and intelligent miners in their employ. Great loss of life has been caused by the ignorance of miners; therefore, to give them the knowledge they so much need, will no doubt prevent loss of life in future.

PREFACE TO THE FIRST EDITION.

THE object which a writer should endeavour always to accomplish is, to make use of such words that every reader may properly understand him, and profit by reading his works.

If the public, or that class of people for whom a work is written, cannot well understand the words written, they cannot profit by the reading, and the labour and time of the author are spent in vain. Therefore, to profit any class of people, in writing works for their better information, it is well if the writer have a knowledge of what such people are capable of understanding; for St. Paul says, 1st Corinthians, 14th Chapter, 9th verse, "Except ye utter by the tongue words easy to be understood, how shall it be known what is spoken? for ye shall speak unto the air." Also, 11th verse, "Therefore if I know not the meaning of the voice, I shall be unto him that speaketh a barbarian, and he that speaketh shall be a barbarian unto me." The words made use of may be proper and good, but are not profitable, if those for whom they are intended cannot understand the meaning of them. Many valuable works have been written on mines and mining by men of talent, but many such works are not understood by miners, who are generally not well educated. The author, having had a practical knowledge of mines and of miners from his youth has, therefore, a better knowledge of what miners require for their better information. The object of his writing the following pages on mines, by way of a conversation between father and son, has been to make use of such words, and in such a manner, that the subject can be perfectly understood by miners. If the end for which the author has written be accomplished, his labour and expense will not be in vain.

St. Helens, Lancashire, April, 1864.

St. Helens, March 14th, 1864.

The undermentioned persons have examined the Plans, &c., connected with the work, and have unanimously pronounced them to be of great practical utility, and the work to be one which has hitherto been much needed by miners at large.

JAMES JERVIS.	ROBERT WOODWARD.
THOMAS HURST.	FRANCIS LYNN.
ROBERT KENYON.	THOMAS ROSBOTTOM.
ALFRED MICKLETHWAITE.	GEORGE PENNINGTON.

Any communications for the Author, addressed care of Mr. CHARLES THRUSH, 23, Russell Street, St. Helens, will be duly received.

A CONVERSATION ON MINES.

The Nature and Quality of Gases.

Son: As you have been in mines, father, from early life, and your ancestors have had, during generations past, a practical knowledge of them, I shall be glad when convenient to have a little conversation with you on mines.—Father: If I can give information by which you and the public may profit, I shall have great pleasure in so doing; and as we have a little leisure time just now I shall be glad, and will endeavour to answer, to the best of my abilities, any question you require information on respecting mines and mining.

Son: Very good. Then I wish to know, father, if carbonic acid gas, which miners often call black damp, and the gas left in mines after an explosion, be one and the same?—Father: No. Gas left after an explosion is much lighter than black-damp, or even common air. This gas will make its way up to the roof, while black damp will lie near the floor. Carbonic acid gas is a combination of carbon and oxygen. It was formerly called fixed air, on account of its being found in chalk, limestone, magnesia, &c.

Son: What are the properties, father, of carbonic acid gas?—Father: Carbonic acid gas (black-damp) is invisible; it is

incombustible and inexplosive, and unfit for respiration. It is a positive poison; it lays violent hands upon its victim, and at once kills him. It is one of the ingredients of after-damp.

Son: What is its composition?—Father: It is found to consist of 6 parts, by weight, of carbon, united with 16 parts of oxygen.

Son: Do you know the composition, father, of after-damp, or choke-damp, as you say it is lighter than black-damp?—Father: It is formed of two parts of watery vapour, one of carbonic acid, and eight parts of nitrogen, the nitrogen being lighter than atmospheric air, and therefore much lighter than black-damp. The nitrogen, you know, is one of the ingredients of the air.

Son: Is there any other kind of gas discharged in mines that you know of?—Father: There is the stone, or white gas.

Son: White gas! What kind is that?—Father: This gas is not explosive, nor is it gas that will die out the candle blaze; the candle will burn well in it, but will not explode it. It would soon kill a person. This gas is found at the time of blasting rock, when gunpowder has too much work—this gas is then produced. Its proper name is sulphuretted hydrogen.

Son: Have you ever seen such gas?—Father: No; I have several times been informed of it by those who have; and, also, a deputy under me had the sinking of a shaft in which this gas was given off, and two of the men sinking with him were lost, and himself very nearly lost—after a shot.

Son: Have you ever experienced the effects of these gases? Some people say they have a choking nature.—Father: I have often been affected by the gases, and have had to be brought home, having been rendered insensible by them, but I never felt the choking sensation that one would expect.

Son: Brought home insensible! then, had you much pain before you were struck insensible? or do you remember anything of what took place?—Father: I remember well that I had no pain, and I was very sick also for perhaps a moment, just before I lost all sensation. My limbs also felt very heavy, so that I was not able to use them.

Son: Would you then be like a person insensible with sleep? Just as a person is not conscious of the moment he passes away into sleep, I presume you would have no knowledge of the time and moment you passed into insensibility? But how long were you in that state of unconsciousness?—Father: I cannot tell how long I had been insensible, as I was at home, brought up out of the pit, when I returned to consciousness. I had been at home a long time before my knowledge of things returned properly, and at the moment of my recovery every person I saw appeared as in a dream.

Son: By this, I presume, father, that all persons lost by explosions with after-damp, suffer very little at death, as they pass away like a person in a sleep?—Father: I believe they know very little until death passes them into eternity. I know had I remained in the pit a little longer I should have passed away without a knowledge of it.

Son: Is carburetted hydrogen gas called by miners explosive gas?—Father: Yes, some call it explosive gas, others fire-damp, and others fire.

Son: What is the composition of the gas burnt on the surface? —Father: It consists of four parts of hydrogen, and two of carbon.

Son: What is the composition of carburetted hydrogen gas, or pit gas?—Father: It consists of four parts of hydrogen, and one of carbon.

Son: Will the gas ignite if not mixed with atmospheric air? —Father: No. It is a combustible only in oxygen or air. One foot of carburetted hydrogen gas requires a mixture of from five to twelve feet of air to cause it to ignite.

Son: Do not miners' candles burn with enlarged flames when working where explosive gas accumulates?—Father: The flame of the candle is enlarged when air and gas are in such quantities as nearly to be an explosive mixture. When one foot of gas is mixed with 13, 14, 15, or 16 feet of air, the candle burns with enlarged flame; but by mixing more air to the one foot of gas, the flame of the candle diminishes to its proper size.

Son: Gas, then, is rendered harmless by *adding* more pure air to the one foot or same quantity of gas?—Father: Just so. It becomes further from the explosive mixture by adding more pure air to it.

Son: What quantity of air does gas require to make it, *when ignited*, at the greatest explosive mixture or power?—Father: One foot of gas mixed with seven to ten feet of air will be near the greatest explosive mixture, or one foot mixed with two of oxygen.

Son: If a miner's working place is full of gas, will not air annihilate or destroy the gas if mixed with it?—Father: No; air will not destroy it, but only render it harmless, if the volume of air be much greater than that of the gas. That is, if twenty feet of air, or more, be mixed with one foot of gas, then, in such mixture the gas is rendered harmless.

Son: It requires, then, a greater volume of air than gas to cause an explosion, and a greater volume, also, of air, to *prevent* an explosion? which looks like a contradiction.—Father: Such is the case. As before stated, a mixture of from five to twelve

feet of air to one foot of gas will cause an explosion; but a larger mixture of air to the same quantity of gas will prevent one.

Son: Is explosive gas elastic?—Father: Yes. Three feet of gas may be pressed into the space of one foot; and, if the pressure be reduced sufficiently, the three feet will expand into six feet or more. Air can be pressed into 40,000 times less space than it naturally occupies, and swelled to 14,000 times larger than it usually occupies.

Son: Then, when the weight is reduced from the gas, the gas expands out of the strata, out of every hole in the roof, and out of old gobs, which may be called magazines of gas, and overflows into the workings and tramroads from every place wherein it is compressed?—Father: Yes; that's the cause of mines producing more gas at one time than at another, and also more when a change takes place in the weather.

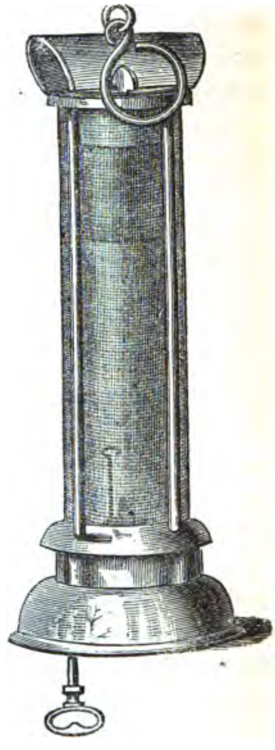
Son: Why does explosive gas make its way up to the roof in mines, and fill holes and stock-working places which lie highest?—Father: Because explosive gas is much lighter than air. Two feet of the gas will weigh only a little more than one foot of air. Because the specific gravity of the atmospheric air is 1·000, and that of explosive gas, 0·555.

Son: Why does carbonic acid gas, which miners call black-damp, lay nearest the floor in mines?—Father: Because it is heavier than air. One foot of black-damp will weigh nearly two feet of air; its greater weight being the cause of its lying nearest the floor. Because its specific gravity is 1·524.

Son: If damp be heavier than air, how can the air current drive it away, or force it along, through the workings and up the upcast? Will not air pass through and the gas settle downwards to the bottom, like mud in water?—Father: Unless the

current of air pass through the workings and along the air-passages, with a force sufficient to overcome the greater weight of the black-damp, it cannot clear the mine, and the black-damp will settle down, as you say.

Son: Safety lamps are used often, are they not, father, in those mines generating explosive gas?—Father: Yes, and great loss of life has often been *prevented* by the use of safety lamps; and yet many have been lost, I fear, by too much reliance on the safety lamp, when the purity of the currents ought to have been attended to by rendering the gases therein harmless.



Son: No doubt, then, you have seen safety lamps used in mines?—Father: Seen them? yes, thousands of times. This is a representation of Stephenson's lamp.

Son: Have you seen gas explode inside the wire-gauze, and not explode the gas outside?—Father: Yes, very often; I well remember, on one occasion, gas came suddenly upon a person and me, and the lamps filled with flame; we lowered the cotton-wick to put out the blaze, but the flame remained within the gauze.

Son: And what did you do then?—Father: We got away to pure air and a safe place as soon as possible, but not before the lamps were red hot, for we had to take them nearly one hundred yards.

Son: I think the safety lamp is a very good invention. Do you know, father, why flame will not penetrate through the wire-work, and explode the gas outside?—Father: Because the inflamed gas within the gauze is so much cooled in its passage through, or by its contact with the gauze, as to cease to burn before it reaches the gas outside.

Son: I do not see, yet, why an explosion taking place within the lamp gauze, should not communicate to, and explode the gas around it?—Father: This is a subject of wonder to even philosophers, and the only mode they have of explaining it is, that flame cannot pass through a fine wire-work, because the wire cools the flame sufficiently to extinguish it in passing through.

Son: But does not the wire often become red hot, by the burning of the gas inside?—Father: Yes, but fortunately, the gas outside the gauze cannot be exploded by red hot wire, the intervention of actual flame being required for that purpose, so that the wire does not set fire to the explosive gas around it.

Son: But if the wire be red hot, how can it cool the flame within, and prevent it passing through the gauze?—Father: The gauze, though red hot, is not so hot as the flame by which it has been heated.

Son: Is it not possible to propel the flame, then, through the gauze?—Father: A strong current of air will propel the flame through.—*See Table A, page* 17.

Son: You say, the engraving is a representation of Stephenson's lamp, is not the lamp like all others?—Father: Stephen-

son's lamp is so constructed as to extinguish the flame the moment gas explodes within it, so that the gauze can never become red hot.*

How Gases are Generated, Accumulated, and Produced in Mines.

Son: What is meant by generating, producing, and accumulating; that is, what am I to understand, father, by the same, as I often hear people say mines generate, produce, and accumulate gases?—Father: What you may understand by the word "generate," is to produce from, to bring from, or to cause. Also the word "accumulate," is to add to, to produce, to multiply, to increase, to collect, or to make more.

Son: But how are gases, then, father, generated, produced, or accumulated in mines?—Eather: There are two ways by which gases may be said to accumulate in mines. All gases are generated or produced, you know, from every stratum, from one end of the whole route of the air-passages to the other. When the air first enters the air-gate, at the down-cast, there is in the first yard of its route a supply of gas. More gases are added as the air passes onwards. Let it pass still forward, and the quantity of gases in it multiplies; yet, as the air goes onward, the flow of gas from every stratum increases, until the same is discharged at the top of the up-cast. This is one way by which

*** On the 20th of February, 1872, an Improved Safety Lamp, invented by Henry D. Plimsoll, Esq., of London, was subjected to some severe experimental tests, performed by Mr. William Utley, underviewer at the Wombwell Main Collieries, Barnsley, the inventor (Mr. Plimsoll), myself, and other friends; and the issue of the experiments was so successful that I have no hesitation in giving an opinion to the effect of its being the best safety lamp yet invented, as the following qualifications, which were fully borne out by the result of the tests, will amply show:—I. It is very sensitive to gas. II. The moment an explosion takes place within the lamp, its light is thereby extinguished. III. By unscrewing the lamp top the light is extinguished, therefore there is no inducement for miners to tamper with it. IV. It gives a very much clearer and purer light. V. The force of the current cannot extinguish its light, be the velocity ever so great. VI. Should an explosion take place within the lamp, there is no possibility of the current propelling the flame outside.**

A.—The following is an extract from the Register of Experiments on Safety Lamps at Hetton Colliery, conducted by the Lamp Committee of the North of England Institute of Mining Engineers, 14TH OCTOBER, 1867.

No.	No. per Register Book.	Lamp.	Velocity of Current. Feet per second.	Time of Duration of Experiment Seconds.	Position of Lamp.	Remarks.
1	1	Common Davy	11½	2	Perpendicular	Fired
2	15	Morrison's No....... 1	15	90	Do.	Still burning (gas turned off)
3	16	Do. 2	14	5	Do.	Out
4	17	Do. do.	do.	2	Do.	Do
5	18	Do, do.	18	4	Do.	Do
6	19	Do. do.	21	24	Do.	Do
7	20	Do. do.	25	23	Do.	Do
8	21	Do. 1	do.	35	Do.	Still burning (gas turned off)
9	22	Do. do.	35	2	Do.	Out
10	23	Do. 2	do.	3	Do.	Do
11	24	Do. 1	do.	1	Slanted top from current.	Do
12	25	Do. 2	do.	1	Do.	Do
13	33	Do. 1	do.	5	Do.	Do
14	41	Do. 2	25	5	Perpendicular.	Do
15	42	Do. 1	do.	11	Do.	Do
16	43	Do. do.	do.	2	Do.	Do
17	46	Do. do.	do.	3	Slanted top from current.	Do
18	50	Do. 2	20	Not ntd	Perpendicular.	Gas turned off by mistake
19	51	Do. 1	do.	10	Do.	Out
20	52	Do. 2	do.	2	Do.	Do
21	55	Do. 1	27	50	Slanted top from current.	Still burning, gas done.
22	56	Do. 2	do.	6	Slanted top to current.	Out
23	57	Cail & Glover	do.	2	Perpendicular.	Fired
24	62	Geordie, with protg. shield	do.	5	Do.	Do

gases accumulate; and the other is, when air cannot get at and round any stocked or undisturbed part of the mine to bring gas away from it. If the air in mines should at any time become stagnant, such mine would very soon fill with gases, by which the accumulation of gases would at once take place.

Son: In those mines, then, where much gas is produced, and there is not a proper quantity of air to dilute it, the accumulation will be very great.—Father: Yes; there is always an accumulation of gas going on in mines, especially if the quantity of air be not sufficient to dilute and render it harmless.

Son: Is there any weight on the strata of coal and stone from where gas is produced, to compress the said gas therein?—Father: There is the atmospheric weight or pressure always pressing against the strata from whence it generates.

Son: What is the pressure of the atmosphere against the strata?—Father: The pressure is nearly 15lbs. upon every square inch of the strata or surface; 2,160lbs. upon one square foot; 5,000 billions of tons pressing upon the whole earth's surface.

Son: Is the amount of gas generating in mines, then, *in proportion* to its overbalancing pressure?—Father: Yes. The escape of gas in mines is like steam blowing away from a boiler. When steam is much compressed in a boiler, the compressed steam, you know, will lift up the weight of the valve, which presses it there, and it will continue to blow away therefrom until its compression is reduced to the weight of the valve; in like manner then gas blows out and generates from the strata, because its compression therein is greater than the weight of the atmosphere.

The cause, or why one Mine Generates and Produces more Gases than another.

Son: Can you show why one mine gives off more gas than another?—Father: Because the compression of gas in one is greater than in another.

Son: Why do not all mines make explosive gases alike in quantity, when the atmospheric weight is equally alike reduced from the strata in all mines?—Father: The atmospheric weight is alike reduced from the strata, but the "compression" of gas is not alike in all mines; therefore, the discharge of gas is not equally alike.

Son: I cannot see why all mines do not discharge alike in quantity, when the weight which presses in the gas is reduced alike in all.—Father: Well, for your better information, I will illustrate the case. Suppose three boilers are full of steam, the weight of each valve 15lbs., the steam in one boiler so compressed that a great quantity of steam blows off; another, not so compressed, blows off less steam; and a third blows off very little, because little compressed. Now, by taking 1lb. weight from each valve, the greatest quantity of steam will blow off from the one most compressed; so, in like manner, will most gas generate in those mines where it is most compressed.

Son: Very good, that I understand; but why, father, is not the pressure of gas in mines alike?—Father: Because the gas has been blowing off longer in some than others.

Son: Will not the great pressure of gas in the strata all blow off in time, as steam will all blow off from a boiler, until the pressure of gas be the same as the pressure of the atmosphere? —Father: In time the two will become alike equal in pressure.

Son: By this I understand the pressure of gas in the strata will become so reduced, that it will press out with only a 15lb. pressure, like the 15lb. pressure of the atmosphere which presses it there, the two then being equal?—Father: Yes; after the great pressure of gas has been reduced there, the two will become equal.

Son: If the pressure of steam in a boiler was reduced to the same weight on the valve,—say if the two were alike equal to 15lbs., no steam then, I presume, father, would blow off, as it could not remove away that which was equal in weight to itself? —Father: No; in that case there would be no blowing away of steam, as it could not (as you say) lift off a weight equal to itself.

Son: Then I presume no gas will generate in a mine after the pressure has become equal to the atmospheric weight?—Father: I do not wish you to understand that no discharge will take place; yet after the pressure has been so reduced very little will discharge.

Son: I cannot see how any gas can make its way out when its pressure is reduced to the atmospheric weight. It will not be able to lift away the atmospheric weight to make its escape. —Father: To look at it that way it would appear no discharge could take place. But you know the atmosphere, as before stated, is always changing. To-day its weight may be 15lbs.; to-morrow, little more than 14lbs. Therefore, when its weight is reduced from 15lbs to 14lbs., the discharge of gas then takes place. The weight of the valve is stationary—not like air, elastic; the weight of the valve cannot press into the boiler, like air working in or out, backward and forward, at every change.

Son: I see a little would generate, but only until its pressure was reduced to the lowest atmospheric weight. Father: When gas is reduced in the strata to the lowest atmospheric weight, say

to near 14lb., and the atmosphere returns to its former weight of 15lb., the atmosphere itself is then pressed into the strata to fill up the space of that gas which escaped when the weight of the atmosphere was reduced to its lowest pressure.

The Cause, or why some Mines Generate and produce a Mixture of Carbonic Acid Gas (Black Damp) and Explosive Gas.

Son: Do not all mines give off alike explosive gas?—Father: No. One discharges carbonic acid gas, which miners often call black-damp; another explosive gas, which miners call fire-damp. But other mines discharge a mixture of the two gases.

Son: You say all mines do not alike discharge explosive gas. One discharges explosive gas, another a mixture of gases, and others carbonic acid gas, or black-damp. I wish to know if all mines make explosive gas alike in quantity—that is, those which give off explosive gas?—Father: No; one gives off a great quantity, another not so much, and a third very little.

Son: You said just now, father, that the weight of the valve is not elastic like air. What am I to understand by the air being elastic?—Father: As air is elastic, it is capable of being pressed into the strata to occupy the same space in the strata as the gas which rushed out.

Son: Is air pressed into the strata, then, to fill up the vacuum and to balance the atmospheric weight after the pressure of gas therein is reduced below it?—Father: Yes. The air works in and out of the strata, and mixes with the gas therein, as the two are elastic, because the same reduced weight which caused gas to swell and work out, will also press air in. Also, the atmospheric weight is never long at a standstill, but works backwards

and forwards against and into the strata, like a man breathing in and letting out air, backwards and forwards.

Son : Do you wish me to understand, then, by this, that the strata afterwards gives off a mixture of air and explosive gas ?—Father : I wish you to understand that when gas is so reduced the strata gives off a mixture of explosive gas and black-damp.

Son : Is the confined air, then, which was pressed into the strata, converted into black-damp ?—Father : I believe such is the case. You know a man by breathing lets air into his body, and that air, when let out, is converted into nitrogen or carbon ; so in like manner, the confined air is, no doubt, converted into carbonic acid gas, or black-damp.

Son : Then mines like this discharge a mixture of explosive gas and black-damp ?—Father : Just so. They discharge the two gases until the explosive gas is exhausted, after which the mine discharges black-damp only.

Son : Is it not surprising ? I see very clearly now, how one mine produces explosive gas, another a mixture of gases, and a third black-damp, or carbonic acid gas. But have you seen air pressed into the strata the way you show ?—Father : I have several times seen air enter into open spaces in coal, stone, and rock, which drew in a candle-flame, and the next day the same open space which drew in the air gave off a mixture of gases, and by observing them, I found the open spaces alternately gave off and let in air as the weather changed.

Son : Have you seen any other thing to convince you the air passed in and out of the strata ?—Father : Yes ; a number of men under my charge were working one day near to the workings of an old colliery. They holed into the old working. When they got a hole through, air passed through the hole into

the old workings like air rushing to an up-cast near at hand. This enabled me and others to travel a great distance on the tramroads belonging to the old workings. The men with me were at a loss to know why air entered through the hole into the old workings; but, as I knew it was only a return of the weight or pressure of the atmosphere, I told them not to be surprised if to-morrow black-damp rushed out of the hole from the old workings.

Son: And was such the case?—Father: Yes. One day we were able to travel into the old tramroads a great distance; another day we were not able to get to the hole from whence damp came out. It was like a weather-glass, or barometer, for the men.

How it is that a Change in the Weather Affects the Workings of a Mine with Gases.

Son: Why are mines affected by a change of the weather?—Father: Because the weight of the atmosphere which presses gas in the strata is diminished. When a change in the weather takes place, the weight of the atmosphere is diminished from 15lbs. to near 14lbs. This diminishing weight of the atmosphere causes an extra discharge of gas, as an extra discharge of steam would blow out of a boiler if a little weight was taken off the valve. The moment the pressure of the atmosphere is reduced, gas expands from every place into which it is compressed.

Son: Do not miners often say, on seeing a cloudy wet morning, they will not be able to work that day? and also say so when the wind blows in a certain direction?—Father: Yes; the miner knows the weather affects his working place, but he has not the knowledge to enable him to understand how it does so.

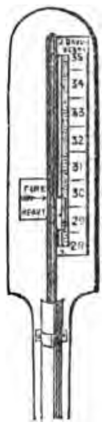
Son: Are all working places so affected as not to allow the men to work when a change of weather takes place?—Father: All are more or less affected, but all are not so much as to prevent men from working in them.

Son: Why are not all affected alike?—Father: Because some mines have very little air for ventilating purposes—only just sufficient to take away the gases on those days when little is discharged. Therefore, when a change of weather takes place, the air is not sufficient to dilute the extra quantity of gas generating.

Son: I see much caution and care are required to prevent explosions. Is there any forerunner to give notice to the men of a change in the weather, so as to have a knowledge of the extra production of gases?—Father: The barometer will show when a change takes place, but will not show before the extra discharge of gas commences. The change in the two is seen at one and near the same time. Therefore, there is nothing to give notice beforehand. I have known an extra discharge of gas to take place before any change has been seen in the barometer. This shows that the gas is "more sensitive" than mercury.

Son: Will you give me a little explanation of the barometer, so that I may understand by it the weights, changes, or pressure of the atmosphere? Such information will give me a knowledge of the time when the weight is reduced which gives place to an outburst of gas, and as a larger quantity is generated from the strata, at such a time, the knowledge is important.—Father: The diagram you see is a representation of the barometer; when a change in the weight of the atmosphere takes place, the fluid or mercury within the tube is set in motion, it moves up or down at every change of the atmospheric weight.

Son: How is the mercury within the tube set in motion by



the atmosphere?—Father: I will give an explanation to your inquiry in the following manner. It has been discovered that water could not be raised more than about 34 feet in the pump, the weight of the atmosphere on the surface of the water being the cause of the ascent of water in the vacuum made in the pump, and that a column of water 34 feet high was, therefore, an exact counterpoise to a column of air which extended to the top of the atmosphere. A column of mercury is much shorter than 34 feet, because mercury is fourteen times heavier than water; therefore, if the weight of the atmosphere will balance 34 feet of water, it can balance only (on the same principle), 29 to 30 inches of mercury.

Son: You say "balance," am I to understand by this, father, that the atmosphere and the mercury are balanced similar to two weights in a pair of scales; the mercury being in one scale, and the atmosphere in the other?—Father: Just so; 29 or 30 inches of mercury within the tube and 34 feet of water, balances the whole weight of the atmosphere, said to extend 45 miles high.

Son: Then when the mercury moves upwards there is more weight of the atmosphere, and a diminishing weight when it moves downwards?—Father: That is the case, you know, if the weight in one scale be increased or diminished, the other scale will either ascend or descend.

Son: If the mercury within the tube of the barometer moves downwards, I may know, then, that an extra quantity of gas is generating from the strata, because the weight of the atmosphere which pressed gas there is reduced?—Father: That is the way. I see you understand, now, the barometer. Fire on the baro-

meter denotes a large quantity of gas generating from every strata in the mine, because the atmospheric weight is reduced. The condition of the air in a colliery depends very much on the state or weight of the air at the surface. As the weight of the atmosphere is shown by the height of the barometer, we can readily see that when the barometer has sunk, the air becomes lighter; and the pressure, which before assisted to keep in the gas, now being diminished, allows it to escape. For every degree which the barometer falls, the pressure per square foot is lessened more than 70lbs. The following valuable table of Mr. Fairley's will show the matter more clearly:—

TABLE OF THE PRESSURE OF AIR AT DIFFERENT HEIGHTS OF THE BAROMETER.

RULE.—Height of barometer in inches × ·4208—weight of a cubic inch of mercury=pressure per square inch in pounds.

Height of barometer in inches.	Pressure per square inch in pounds.	Pressure per square foot in pounds.
27·	13·25	1908·23
27·25	13·37	1925·89
27·5	13·49	1943·56
27·75	13·61	1961·23
28·	13·74	1978·90
28·25	13·86	1996·56
28·5	13·98	2014·24
28·75	14·11	2031·91
29·	14·23	2049·58
29·25	14·35	2067·25
29·5	14·47	2084·01
29·75	14·60	2102·58
30·	14·72	2120·24
30·25	14·84	2137·92
30·5	14·96	2155·59
30·75	15·09	2173·26
31·	15·21	2190·93

Son : When are mines in the greatest danger?—Father : Some are always in danger, if there is not sufficient pure air to dilute and render harmless the gases.

Son : Yes. But from changes in the weather?—Father : The greatest danger is when there is a sudden fall in the barometer, and a sudden rise in the thermometer, at one and the same time.

Son : How is that?— Father: Because a fall in the barometer, as before stated, gives place to a larger outlet of gas, because the atmospheric weight is then diminished, and a rise in the thermometer diminishes that air in the mine, which should dilute the gas. The two taking place at one time, cause much danger.

Son : I understand; a rise of the thermometer shows a rise of the temperature, or a greater amount of heat?—Father : Just so. By this rise, the ventilating power is reduced; not only so, the density of the air is also diminished by both ; so that there is not the same quantity of air passing in the current through the *same area* in the *same space* of time. And the temperature rises much, you know, from winter to summer.

The Natural Ventilation in Mines.

Son: Do you know what are the several changes of the temperature, or the degrees of heat and cold between summer and winter?—Father : In England the temperature is often changing —to-day very high; to-morrow it may have fallen several degrees.

Son : What am I to understand by a fall and rise of the temperature?—Father : You may understand the rise and fall in the following manner :— When the mercury in the thermometer stands at 32 degrees, the temperature is at freezing point, below that is extreme cold ; 55, is temperate heat ; 76, summer heat ; 98, blood heat ; 112, fever heat ; at 176, spirits boil ; and at 212 water boils.

Son : I see now ; if the temperature should suddenly rise from say, 32 to 60 degrees, the change of temperature would be very great, and might cause people to sweat ; but to fall from 60 to 32 degrees would make an extra coat to be required ?—Father : Just so. I find you understand the rise and fall of the temperature ; it often rises and falls suddenly in England.

Son : I understand it, because I have had a practical knowledge of such changes. Can you give me the lowest, and also the highest degree of temperature in each month for one year ? Any year will do.—Father : Yes ; I will try to give it you. But I wish you to understand that the temperature is not equal, on the same day, in every part of England ; it may vary a few degrees in one place from that to another. Therefore, I will give the temperature at Manchester for each month in the year 1852.

	Dates.	*Lowest Degrees.*	*Dates.*	*Highest Degrees.*
January......	12th	21	15th & 21st	50
February......	11th & 21st	29	24th	54
March........	8th, 9th, & 11th	30	23rd	61
April..........	4th	33	15th	64
May............	4th	34	8th, 17th, 20th, & 24th	64
June...........	1st	42	6th & 20th	69
July............	23rd	51	4th	83
August.......	11th	50	1st & 17th	71
September...	17th	38	5th & 8th	7C
October......	8th	35	22nd	60
November...	29th & 30th	32	8th	61
December...	8th	31	5th	56

Son : Many thanks for the information. The temperature changes a good deal from summer to winter. The lowest degree in that year, I see, was 29, and the highest 83 degrees—one very cold, the other very hot. I think the temperature in the

underground workings of mines does not so change. I have seen miners, in going down the pit into the workings in winter, all anxious to go down at once, if possible, to get out of the cold, the mine being warm, but in summer the mine is cooler than on the surface. Why is it so?—Father: The underground workings may appear on first entering more cool in summer than in winter, but it is not so; the temperature of the mine is nearly the same all the year round, unless more men are employed, and the works more extended. It is you only who feel the change in passing from a high degree of temperature, on hot days in summer, to a lower temperature, but in winter from a low temperature to a higher one.

Son: Is the temperature alike equal in all mines?—Father: No; the temperature is much higher in some mines than in others.

Son: Why is it much higher in some mines than in others? —Father: Because more men and horses are employed in some mines than in others. The pits are deeper, and the works more extensive, &c., &c.

Son: How is heat produced by men, horses, deep mines, &c.? —Father: The temperature of mines is due to several causes. At a certain depth from the surface, the temperature in England is invariable through the year, and does not sensibly differ from the mean annual temperature, which may be taken at 50 deg. F. Below this "line of no variation," the temperature continues to increase as we descend. The general result obtained by a comparison of many observations shows that the increase of temperature is—

In the first 200 yards..about 1 deg. F.	for every		50ft.
In the second 200 yards...	do.	do.	70ft.
In the third 200 yards..	do.	do.	85ft.

Also miners, by respiration, produce heat, and their lamps produce nearly the same amount; again, there are various chemical actions going on, each of which is a source of heat; there is also slack or rubbish left in heaps for a considerable time, during which heat is thrown off; by all of which the temperature of a mine is raised.

Son: I should be glad if you would inform me the height to which the temperature in mines is raised. I should then know nearly the lowest and the highest temperature on the surface, and also the highest temperature raised by natural heat in mines. —Father: I can give the highest natural heat of several large collieries; and, I think, the highest known to have been produced. Some mines, as you know, produce more natural heat than others.

Son: My object is to get a knowledge of the highest natural heat produced in mines. Is the natural draught or the natural ventilation produced by the natural heat?—Father: Yes. The natural heat of mines is the power or cause, and the natural draught the effect produced by that cause. Remove the cause, and the effect will cease.

Son: I remember a good deal has been said in reference to this natural ventilation in mines. Some say there is a constant continuation of this natural current passing through the workings, and others say there is not a constant current all the year round. Therefore, I should like to ask a few questions on the subject. Do you know the highest degree of the natural heat in mines?—Father: The temperature of the down-cast at the cannel pit, Ince Hall, Wigan, on the 13th of January, 1853, was 42 degrees, and the temperature of the workings was 62 degrees. This will show the natural heat of the mine to be 20 degrees higher than the air at the down-cast. On the 16th of December,

1852, the temperature at the down-cast pit at Seaton Delaval Colliery was 42 degrees, and the average temperature of the mine 50 degrees, or 8 degrees above the air at the down-cast. At the Tyne Main Colliery, when an experiment was made, the natural heat of the mine showed a difference of 20 degrees between the down and up-cast shafts. At the Hetton Colliery, the natural heat of the mine was found at one experiment to produce between the down and up-cast shafts a difference of 28 degrees; but this experiment was made at a time when the temperature on the surface was very low. I am only sorry that the temperature of the surface was not given at the same date. To fix the temperature, then, on the surface, at 34 degrees, when the experiment took place at Hetton Colliery, it would show the natural heat of the mine to be 62 degrees, the same as at the cannel pit, Ince Hall, Wigan. Thus we arrive at nearly the highest temperature produced by the natural heat in mines.

Son: Is not the natural heat, then, constant in mines?—Father: Yes, always the same, summer and winter.

Son: Then if always the same, will it not always produce the natural draught?—Father: No; the natural draught is diminished or increased, according to circumstances.

Son: Pray let me know what those circumstances are; for I cannot see why there is not always the natural draught in mines when the natural heat by which it is produced is always the same?—Father: Let me first show when the natural draught is there, after which I will show when it is not.

Son: That is just what I wish you to do.—Father: Well, you remember I have just stated that the temperature of the mine is sometimes 20 and 28 degrees higher than the temperature of the air coming from the down-cast.

Son: I remember.—Father: When that is the case—that is, when the temperature of the underground workings is higher than the air on the surface—there is always the natural draught. In winter, when extremely cold, it produces a large current. You know if the temperature on the surface be down at 30 degrees, and the air in the mine 62, the heat will be 32 degrees above that on the surface. This would give a large natural current.

Son: How does the natural heat produce the current?—Father: Heat, you know, as I have often before stated, expands the air so that one cubit foot of warm air is not the same weight as one cubit foot of cold air; therefore, warm air being much lighter than cold, rushes up the up-cast as corkwood in water, or as a balloon through the air.

Son: I see now how the heat of the mine produces the natural draught, but what has the heat of the mine to do with the cold air on the surface?—Father: Well, it has this to do with it. When the cold air on the surface passes down into the mine, it is increased in temperature, and thus the natural current is produced. You know, if the temperature of the air on the surface was, say 83 degrees, there could not be an increase in temperature by passing it to one—say 62 degrees.

Son: In that case the natural heat of the mine would not be above, but below the temperature of the air on the surface.—Father: Just so. I will illustrate the case. Suppose it was winter, and you had a pair of scales so large and so constructed that you could weigh in one scale all the hot air that filled the up-cast shaft, and could fix in the other scale all the cold air which filled the down-cast shaft.

Son: By this illustration I can see your object. You say that one foot of warm air weighs much less than one foot of cold

air.—Father: I did. Therefore, if you balance the hot and the cold air, you will find the cold air in the down-cast scale will outweigh the hot air in the up-cast scale; but suppose it is summer, when the temperature of the air on the surface is, say 83 degrees, and you fill your down-cast scale with this hot expanded air, will this expanded air, at 83 degrees, then overbalance the air in the up-cast scale, at 62 degrees? No, impossible, unless there is another power or weight in the scale to assist in weighing it down. I can no more believe it than I can believe 1lb. will weigh down 2lbs.

Son: I think it is clear enough to be seen by every person. As you say, the natural heat of the mine being much higher in temperature than the air on the surface, the cold air, in passing through the workings to the up-cast, is by the heat therein much expanded, therefore the same number of cubic feet of hot expanded air in the up-cast is much less in weight than the heavy cold air in the down-cast; and, as there is not the same weight in one as in the other, one falls down and the other ascends just as a 2lb. weight would weigh down a 1lb.—Father: I see now you understand a little when and how the current is produced in mines.

Son: Yes; and I understand also when it is not.—Father: Do you? Be not so confident, my lad. Remember, I have been informed there is a pit near Dudley Hill in which it was said the natural current continued without ceasing for 18 months.

Son: They may say it was the natural current; but I see the subject so clearly, that it is impossible to make me believe it, unless I knew there had been no hot days during the summer on which it had taken place, because the hot air on the surface is in summer many degrees higher than the hot air in the up-cast shaft

when no furnace is at work; consequently, it becomes much lighter in weight, and cannot weigh down the other when it enters into the down-cast scale; and it being overbalanced, there is a stand, or no natural ventilating current.—Father: I am glad your views on the subject are the same as mine; yet I have several more statements to make on the natural ventilation of coal mines.

Son: You say when the air is made hot, it expands, and thus each cubic foot of air becomes lighter as the temperature increases. Do you know the weight of a cubic foot of air at temperatures varying from 32 degrees to 222 degrees?—Father: See, I have a table here. By it you may find the difference in the weight of a cubic foot of air from a temperature of 32 to 222 degrees.

SHOWING THE EXPANSION OF THE HEATED AIR, AND ITS WEIGHT.

Degrees of Heat.	Weight of a Cubic Foot in grains.	Volume.
32	550	100
42	539	102
52	529	104
62	518	106
72	506	109
82	495	111
92	487	113
102	479	115
112	470	117
122	461	119
132	453	121
142	446	123
152	439	125
162	432	127
172	426	129
182	420	131
192	413	133

202	407	135
212	401	137
222	394	139

Therefore, suppose you have a pitful of air, at a temperature of say 32 degrees, and one at 62 degrees, you may find by the table the difference in the weight of the two.

Son: Suppose two shafts are equal alike in depth and area, each say 300 yards deep, and 153 square feet area, one shaft the down-cast, and the other the up-cast, the temperature of the air in the down-cast is 42 degrees, the air in the up-cast is 62 degrees, do you know what the weight of air will be in one shaft more than in the other?—Father: You may soon find the difference in the weight of the two. All you have to do is to get a knowledge of the table, and make your calculations accordingly.

Son: If, then, the temperature on the surface increased the air in the down-cast to the same temperature as that in the up-cast (produced by the natural heat of the mine), 62 being the degree, will not the same weight of air be in the one shaft as in the other, because the temperature of the two shafts would be equal? And if so, by the same natural laws, if the heat on the surface in summer increased the temperature of the air in the down-cast 20 degrees above the natural heat in the up-cast, one being at 82 degrees, and the other only 62 degrees, would not the air which filled the down-cast scale weigh less than the air in the up-cast scale?—Father: Just so, but it could not propel air down into a mine and through the workings with the temperature of the air so much higher in the down-cast than in the up-cast. No ventilation can take place until the air be propelled by another power. For your better information I will give you another table, to enable you to find the difference in the weight of air in proportion to the difference in temperature. Here it is.

Table of the Pressure of the Air,

In lbs. avoirdupois per square foot of surface of area of shafts of different depths, and subjected to different degress of temperatnre. DEPTH OF SHAFTS, IN FEET.

Temperature.	120	180	240	300	360	420	480	540	600	660	720	780	840	900	960	1020	1080	1140	1200
deg.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lns.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
32	9.710	14.565	19.421	24.276	29.131	33.986	38.842	43.697	48.552	53.407	58.262	63.118	67.973	72.828	77.683	82.538	87.394	92.249	97.104
40	9.555	14.332	19.109	23.887	28.664	33.442	38.219	42.996	47.774	52.551	57.328	62.106	66.883	71.661	76.438	81.215	85.993	90.770	95.548
50	9.367	14.051	18.734	23.417	28.101	32.784	37.468	42.152	46.835	51.519	56.202	60.886	65.569	70.252	74.936	79.620	84.303	88.987	93.670
60	9.187	13.780	18.373	22.960	27.560	32.153	36.746	41.339	45.933	50.526	55.119	59.712	64.306	68.899	73.492	78.085	82.679	87.272	91.865
70	9.013	13.519	18.026	22.532	27.039	31.545	36.051	40.558	45.064	49.571	54.077	58.584	63.090	67.597	72.103	76.609	81.116	85.622	90.129
80	8.846	13.268	17.691	22.114	26.537	30.960	35.383	39.806	44.228	48.656	53.074	57.497	61.920	66.343	70.765	75.188	79.611	84.034	88.457
90	8.684	13.027	17.369	21.711	26.054	30.396	34.738	39.080	43.423	47.765	52.107	56.449	60.792	65.134	69.476	73.818	78.161	82.503	86.845
100	8.529	12.794	17.058	21.323	25.587	29.852	34.117	38.381	42.646	46.911	51.175	55.440	59.704	63.969	68.233	72.498	76.763	81.027	85.292
110	8.379	12.569	16.758	20.948	25.138	29.327	33.517	37.707	41.896	46.086	50.276	54.465	58.655	62.845	67.034	71.224	75.414	79.603	83.793
120	8.235	12.532	16.469	20.526	24.704	28.821	32.938	37.055	41.173	45.290	49.407	53.525	57.642	61.759	65.877	69.994	74.111	78.228	82.346
130	8.095	12.142	16.189	20.237	24.284	28.332	32.379	36.426	40.474	44.521	48.569	52.616	56.663	60.711	64.758	68.805	72.853	76.900	80.948
140	7.959	11.939	15.919	19.899	23.879	27.859	31.838	35.818	39.798	43.778	47.758	51.738	55.717	59.697	63.677	67.567	71.637	75.616	79.596
150	7.829	11.743	15.658	19.572	23.487	27.401	31.316	35.230	39.145	43.059	46.973	50.888	54.802	58.717	62.631	66.546	70.460	74.375	78.289
160	7.702	11.554	15.405	19.256	23.107	26.958	30.810	34.661	38.512	42.363	46.215	50.066	53.917	57.768	61.619	65.471	69.322	73.173	77.024
170	7.580	11.370	15.160	18.950	22.740	26.530	30.320	34.110	37.900	41.690	45.480	49.270	53.060	56.850	60.640	64.430	68.220	72.010	75.800
180	7.461	11.192	14.923	18.653	22.384	26.115	29.845	33.576	37.307	41.037	44.768	48.499	52.229	55.960	59.690	63.421	67.152	70.882	74.614
190	7.346	11.020	14.693	18.366	22.039	25.712	29.386	33.059	36.732	40.405	44.078	47.752	51.425	55.098	58.771	62.444	66.117	69.791	73.464
200	7.235	10.852	14.470	18.087	21.705	25.322	28.940	32.557	36.175	39.792	43.410	47.027	50.645	54.262	57.879	61.497	65.114	68.732	72.349
210	7.127	10.690	14.253	17.817	21.380	24.944	28.507	32.070	35.634	39.197	42.761	46.324	49.887	53.451	57.014	60.577	64.141	67.704	71.268
212	7.106	10.658	14.211	17.764	21.317	24.869	28.422	31.975	35.527	39.080	42.633	46.186	49.739	53.291	56.844	60.397	63.949	67.503	71.055

This valuable table is by Mr. Fairley's colliery manager. If you wish to know the weight of air in a shaft of a certain depth and temperature, all you have to do is to multiply the area of shaft by the number of lbs. and strike off the three decimal figures on the right hand of the result, and the remainder will be the total weight of air in lbs. in a shaft of that depth and temperature.

Son: Are there more powers than one to propel air down into a mine; and, if so, what are the other powers?—Father: The powers are numerous. There is the mechanical power. Waterfalls in the down-cast are another power. There are also hoppers constructed at the top of the down-cast, so that into them the force of the air on the surface can blow; this may be called also a power to propel air.

Son: Do you know what quantity of air has been produced by the natural heat of the mine?—Father: I can give you a little information on that. Some few years ago, in Yorkshire, I had two collieries under my charge. We had only two pits at one colliery, a down-cast and an up-cast. We had no ventilating furnace, neither had we any explosive gas, but only carbonic acid gas. In winter, when the temperature on the surface was low and extremely cold, the force of the ventilating currents in the mine was so strong as to blow out naked lights. As summer advanced, and the temperature on the surface rose, the force of the ventilating current diminished accordingly, until it ceased to exist; then a fire had to be fixed in the up-cast. The above method was in use not only for eighteen months, but for six years.

Son: Can you show any more collieries where a large natural current was produced?—Father: Yes. At the Tyne Main Colliery the natural heat of the mine produced a natural current

of 34,955 cubic feet of air per minute. The temperature in the up-cast, caused by the heat of the mine, was 20 degrees above that in the down-cast. After this the furnace was put to work; then the temperature in the up-cast rose to 94 degrees above that in the down-cast. And so, accordingly, the extra heat from the furnace increased the ventilating current to 101,876 cubic feet per minute. The depth of the up-cast was 280 yards, and 59 square feet area.

Son: Can you name any more collieries where the natural draught was known?—Father: Yes; you have often, no doubt, heard of the Hetton Colliery.

Son: Hetton Colliery! Yes, very often. Some say there never was produced at Hetton the quantity of air as stated by them.—Father: But before so saying it would be well to know the capabilities of the colliery to produce the quantity. The up-cast pit is 300 yards deep, 153 square feet area, and is provided with three powerful ventilating furnaces; and, to my knowledge, they once had 16 separate divisions of air. Gentlemen disinterested in the colliery have often made experiments, and they say more than 190,000 cubic feet of air were produced per minute. It would be no profit to them to say otherwise.

Son: When experiments were made by them, did they say what quantity of air was produced by the natural current, and also the amount of air added to it by furnace power?—Father: I stated, you know, before, that a temperature of 28 degrees had been produced by the heat of the mine—that is, the temperature of the up-cast was 28 degrees above the temperature of the down-cast. Well, this natural heat of the mine produced 127,145 cubic feet of air per minute. Then the furnace was put to work, and the difference of temperature between the two shafts

rose to 86 degrees. This raised the ventilating current to 208,466 cubic feet per minute. This will show that, in this case, furnace power only added to the natural current 81,321 cubic feet per minute.

Son : I think that production of air by the natural heat of the mine was very large.—Father: I think the same. Yet natural ventilation cannot be depended on. Others bear testimony to the same.

Son: Have you any more remarks to make on the Hetton Colliery, or on any of the others?—Father: I might name several more; yet what I have said is, I think, sufficient on that subject. But, that you may have another opinion besides mine, I will quote a portion of what was stated at Manchester by the late J. J. Atkinson, Esq., Inspector of Mines.

Son : What did he say?—Father: He said, in order to find the ventilating pressure, and the power arising from the use of a ventilating furnace, we require to know the weight of a cubic foot of air at different temperatures and under different pressures. Careful experiments show that 459 cubic feet of air at 0°, or zero of Fahrenheit, the common thermometer, weigh 39·76lbs., when the pressure is 30 inches of mercury of the density due to 32°—a pressure equal to nearly 14¾lbs. per square inch, which is the ordinary pressure of the atmosphere; but it only weighs 1-30th of this, or 1·3253lbs. when the pressure is only one inch of mercury; and since 459 feet of air at 0° expand exactly a cubic foot for each degree of heat added, we get the following *rule* to find the weight of a cubic foot of air at any temperature and under any pressure:

$$W = \frac{1{\cdot}3253 \times I}{459 + t}$$

Where I = the height in inches indicated by the barometer, and t = the temperature by Fahrenheit's thermometer. At 38°, under a pressure of 30 inches of mercury, 100 cubic feet of air weigh just 8lbs.; a box five feet every way would just contain 10lbs. of such air. On one occasion, at Hetton Colliery, when 225,176 cubic feet of air per minute were circulating, the average temperature of the air in the down-cast shaft was 43½°, and that of the air in the up-cast shaft was 211°. Now by the rule given (if we take the barometer half-way down the shaft to have shown a pressure of 30½ inches of mercury), the weight of a cubic foot of air, taking the average in the down-cast shaft, would be ·08044lb.; and the pit being 900 feet deep, this air would produce a pressure of ·8044 × 900 = 72·539lbs. on each square foot by its mere weight. The air in the up-cast shaft, owing to its being hotter, would be lighter, and only produce a pressure on each foot = 54·297lbs.; and hence the difference of pressure on each square foot of area, between the two columns of air, would be = 18·099lbs. Now to find the horses' power producing ventilation, we require to multiply this difference of pressure of 18·099lbs. on the square foot, by the number of cubic feet of air circulating per minute; and then to divide the result by 33,000, the number of pounds raised one foot high per minute by a horse power. In this case, then, we find the ventilating power at Hetton Colliery must have been:

$$\frac{\overset{\text{lbs.}}{18{\cdot}099} = \overset{\text{c. ft. pr. min.}}{225{,}176}}{30{,}000} \times 123\tfrac{1}{2} \text{ horse-power.}$$

225,176 cubic feet of air per minute being in circulation at the time. Some part of the extra heat of the air in the up-cast

over that in the down-cast shaft would have arisen from the heat of the mine, and would cause what is called a natural ventilation, even if furnaces had not been used. But natural ventilation, said Mr. Atkinson, is generally very small in amount, and cannot be depended upon, as in hot weather the down-cast column of air is little or no cooler or denser than the air in the up-cast, and, by making the weight or pressure of the two air columns equal, is liable to stop all ventilation. There is, my son, much valuable information to be had from mine inspectors if miners would only read their lectures and reports; but many miners, I think, choose to remain in ignorance.

Son: I see Mr. Atkinson is also of opinion that there is little or no natural current in hot weather, and that the difference of pressure on each square foot of area between the down-cast and the up-cast at Hetton Colliery, with the large temperature in the up-cast of 211°, was near 18·092 lbs. I wish to know how to find in this case the total weight of air in the down-cast over that in the up-cast.—Father: All you have to do is to multiply 18·099 by the area of the pit, which is 153 feet, and strike off the three decimal figures on the right hand of the result, and the remainder will show the total weight of air in pounds more than in the up-cast.

How wonderful are Nature's Laws, and do not such laws show how wise is he who made them? I should like to have a little information on the force of air in mines.—Father: What do you wish to know of the force of the air?

Son: Can you tell what force the air would be at, on one square foot, at a velocity of from one mile per hour to say 40 miles per hour, and also the number of cubic feet of air that would pass, per minute, through one foot area of the said

velocity?—Father: I had better give you the table. Here it is—

TABLE 1.—Showing the air to travel at a velocity from 1 mile to 40 miles per hour.	TABLE 2.—Showing the quantum of air that passes through 1-ft area per minute in proportion to the velocity.	TABLE 3.—Showing the perpendicular force of the air in proportion to its velocity, on 1 sq. foot in lbs.		
		lbs.	oz.	drs.
1	88	0	0	1¼
2	176	0	0	5
3	264	0	0	11
4	352	0	1	4¼
5	440	0	1	15½
6	528	0	2	14
7	616	0	3	15
8	704	0	5	1
9	792	0	6	7½
10	880	0	7	14
11	968	0	9	9
12	1056	0	11	8
13	1144	0	13	8
14	1232	0	15	12
15	1320	1	1	13
16	1401	1	4	4
17	1496	1	7	4
18	1584	1	9	14
19	1672	1	12	11
20	1760	1	15	8
21	1848	2	2	14
22	1936	2	6	4
23	2024	2	9	10
24	2112	2	14	0
25	2200	3	2	0
26	2288	3	6	0
27	2376	3	10	1

28	2464	3	14	0
29	2552	4	2	5
30	2640	4	6	10
31	2728	4	11	13
32	2816	5	1	0
33	2904	5	7	1
34	2992	5	13	3
35	3080	6	3	5
36	3168	6	8	8
37	3256	6	13	14
38	3344	7	2	12
39	3432	7	8	5½
40	3520	7	14	0

At a velocity of 24 miles per hour, 2,112 cubic feet of air, you see, pass per minute through one foot area at a pressure or force of 2lbs. 14oz. on one square foot.

Son: Do you know at what velocity air travelled at some of the collieries?—Father: Yes; at the Cannel Pit, Ince Hall, Wigan, its velocity by furnace power up the shaft was 1,303 feet per minute, or nearly 15 miles per hour. The velocity of the air at Hetton Colliery, when 225,176 cubic feet of air were produced, was near 1,472 feet per minute, or 17 miles per hour.

Son: Why I want to know is this. If a ventilating engine should propel air at a velocity of 17 miles per hour, will the force or the velocity of that air suddenly come to a standstill the moment there is an accident or stoppage?—Father: No. The ventilating current would continue after the accident, until brought to a standstill by the friction in its route. There is a force in the air, and the force in it is similar to the force in a fly-wheel, when revolving. The fly-wheel would continue to revolve, until the force in it was reduced and brought to a stand by friction: and so in like manner will the velocity or the force in the air current

continue until the friction in the air passages reduces it to a stand, or the density becomes equal in the two shafts.

Son: I should like to know how long the force of the ventilating current would continue after the accident with the engine?—Father: As you do not know the force or density in the air, nor the amount of friction which would have to overcome it, you will not be able to know how long the current would continue. I said the fly-wheel would continue to revolve after the accident, until brought to a standstill by friction; but I wish you to know at the same time it would have to be disconnected from the engine, at the time of the accident, if it continued to revolve; if not it would suddenly stop with the engine; and so in like manner, the ventilating apparatus would have to be so constructed, that when an accident took place, the ventilating current must be disconnected from it, so that the current could continue on its passage, or it would, like the fly-wheel, suddenly stop.

Son: If the engine, or the apparatus connected therewith, could be so constructed as not to stop the force of the ventilating current, would there not then be time sufficient to get out the men before an accident took place in the workings with the generating gases?—Father: It is my opinion there would be time, if so constructed.

Son: I think, father, I have a good knowledge now, how mines discharge gases. I shall be glad to know how mines are ventilated, and also to know the best way of ventilation to prevent loss of life; as there is often great loss of life by explosions, and great loss of life caused by not ventilating properly.—Father: I will give you a knowledge of several ways of ventilating mines before I have done, as well as a knowledge

of the best way, and what I say I know no one can contradict. Explosions there have been, and I fear always will, and so also loss of life, but such great loss of life can be prevented.

How it is that Air is Propelled down, through, and around the Workings of a Mine.

Son: Are not mines ventilated by a large furnace at the bottom of the up-cast shaft?—Father: Yes; but there are also the steam-jet, the bellows, and the fan employed for ventilating mines.

Son: Well, but they do not, I presume, draw or pull air like the furnace through the workings of a mine?—Father: Air is not drawn through the workings by the furnace.

Son: Miners often say, the larger the furnace, the more air will it pull through holes and places nearest the up-cast.—Father: I know miners often say and think so; they know no better.

Son: If air is neither drawn nor pulled, how is it caused to pass through the workings?—Father: Heat, you know, will make almost everything expand, and as air is elastic, cold air expands very much by heat; therefore, the furnace produces ventilation by making air hot at the bottom of the up-cast.

Son: Then, when air expands, does it become lighter in proportion to its bulk with the cold air?—Father: Yes. If one foot of cold air expands by heat into two feet, the two feet, you know, will only weigh the same as one foot.

Son: Then heat makes air so light that it rushes like a balloon up the up-cast and out of a mine? Father: Yes; and with the air rushing up one shaft, the great weight of air in the

other is too heavy to remain in its place; therefore, it falls down or rushes forward to occupy the place of the hot air.

Son: I see; a furnace is like a pump emptying two shafts filled with water—as the water is pumped out of one it receives a fresh supply, which rushes in, owing to its great weight, from the other shaft to occupy the place of that pumped out.—Father: Yes: if two shafts and the workings were full to the surface with water, the yard of water nearest the bottom would be pressed upon by the whole weight of water above it, and the water in the workings between the shafts would be pressed upon by the water from each shaft with an equal force. And it would remain stagnant or motionless, unless an outlet was made for it, because the pressure of water in one shaft would be equal to that in the other. So in like manner will air press towards the up-cast as its weight diminishes between the two.

Son: Air is not pulled, then, as miners often say, like something pulled or drawn with a rope, but is pressed into the up-cast by the great weight of cold air in the down-cast. But how does a steam-jet, a bellows, and a fan ventilate mines, as air is not made hot by them?

Father: Well, as you have asked me questions, all of which I have answered to the best of my ability, I will now ask you a few.—Son: I fear I shall not be able to answer your questions.

Father: The questions I require you to answer will be very simple.—Son: If so, I will try to answer them.

Father: By way of illustration, then, I will suppose you to have a pair of scales, with a 15lb. weight in one scale, and a 15lb. weight in the other: will the weight of one overbalance or weigh down the other weight?—Son: No. The scales would be at a standstill, because the weight would be equal in the two.

Father: You are right, but, if you add 1lb. more to one of them, making 16lbs. in one and 15lbs. in the other?—Son: That being the case, the 16lb. weight would be sure to weigh down the other.

Father: I see you are able to answer; but again suppose you take off 1lb., making 15lbs. in one and 14lbs. in the other? —Son: If so, the 15lbs. weight would weigh down the 14lbs. the same as the 16lbs. weighed down the 15lbs.

Father: Very well. Now by this I wish you to understand that the atmosphere presses with a weight of 15lbs. into and upon the top of the up-cast as well as into and upon the top of the down cast, and as two 15lbs. will not overbalance each other but be at a standstill, so, in like manner, will air in mines be at a standstill with an atmospheric weight of 15lbs. pressing at the top of each shaft, unless the weight is diminished or increased at either the one or the other. That is to say, all that is required to cause air to pass down one shaft and up another, is either to add to or diminish the weight of the atmosphere at either the one or the other shaft.

Son: Will the steam-jet, bellows, and fan diminish or increase the atmospheric weight at the top of either shaft?—Father: They will send in a greater pressure, or force out the air at the top of the upcast to diminish the pressure. Therefore, in proportion to its force they diminish or increase the pressure of the air by which ventilation is produced.

Son: How wonderful, father, is ventilation, and yet so clear that if a blind man cannot see it he is as dark as midnight. But may a steam-jet or fan, &c., be fixed to work at the top of either shaft?—Father: They may; as the amount of air produced for the workings will be just the same, if fixed at one

shaft or at the other. You know a pound of pressure, added or diminished, is like the scales—one and the same. Yet the steam, no doubt, would affect the workings if the jet were fixed at the top of the down-cast. In the steam-jet there are two powers of ventilation. One is its propelling force, the other is the high temperature of the steam, therefore it would do more work by fixing it in the up-cast shaft.

Son: I think many persons believe that the same quantity of air is not produced alike, by a ventilating engine being fixed at one shaft, as at the other?—Father: Some believe the quantities of air produced by both ways are precisely alike the same: others believe not so, or say otherwise.

Son: Much discussion has arisen from time to time, I believe, on this subject?—Father: Yes. This subject of propulsion has been the cause of much discussion with men of talent. I, and an eminent viewer (as I was informed he was) near Durham, who signed himself "Miner," spent nineteen weeks' controversy on the same subject.

Son: Indeed; then I shall be glad to have your views on the subject of propulsion?—Father: My object, you know, is to give information; therefore you may ask anything on the subject of ventilation.

Son: I wish to ask, would there be any current in mines without motion?—Father: No.

Son: With the air being elastic, as you call it, would there be any motion of the current without additional increase in the density at one end of its exit, more than at the other?—Father: No; it would be impossible.

Son: Would there be any increase in the density without additional weight?—Father: No; it could not be.

Son: Then additional weight to the current must produce an increased density?—Father: Yes.

Son: And that increased density, where there is an open exit, produces motion?—Father: Just so.

Son: And that motion of the air, then, is the current produced?—Father: So it is.

Son: Then additional weight to the air, at one end of its open exit, produces both motion and density at the same time? —Father: Such is the case.

Son: Why is it so?—Father: Because it is a law in nature that one cannot act without the other.

Son: Is it correct, father, that we live at the bottom of a very deep sea?—Father: So it is. The sea is forty-five miles deep. It is not, you know, a sea of water, but a very deep sea of air.

Son: A deep sea of air! Our coal mines and pits, then, are filled with air just in like manner as they would with water if at the bottom of the ocean?—Father: Just so. All pits and workings are filled and pressed down with air to overflowing.

Son: Pressed down, do you say? Then the air at the bottom of this deep sea presses upon bodies and substances which lie on its floor, or on the earth's surface?—Father: The weight and density of the air on the surface of the earth is very great.

Son: What am I to understand, father, by the density of the air, for I have often heard of density?—Father: You will understand if two feet of air are pressed into one foot, the one foot is much increased in density, but diminished if one foot of air swells and expands out into two feet.

Son: I well understand now when an increased and a diminished density of the air takes place.—Father: And you will also understand, no doubt, if two feet of air are pressed into one

foot, the one foot will weigh just the same weight as two feet before, and also if one foot swells and expands out into two feet, the one foot of expanded air will weigh one-half only of what it did before.

Son: It is clear enough, father, for any person to understand, and they should never forget it. Do you know the weight of air pressing on the surface of the earth?—Father: The average weight of the air pressing on the earth's surface is near 15lbs. per square inch.

Son: This atmospheric weight of 15lbs. presses then upon the top of the up-cast, and also upon the top of the down-cast shaft? —Father: It is so, and with a weight such as that is, the density of the air is very great in the workings of a mine.

Son: There is a natural heat in mines?—Father: Yes; and in some this natural heat is a great ventilating power.

Son: How does the natural heat, father, produce then a natural current?—Father: In the following manner: the heat of the mine expands and swells out the air, by which it becomes much diminished in density, and also much less in weight, so that it rushes up the up-cast.

Son: Is the air obtained, then, from the down-cast, by propulsion?—Father: It is, always, and by this natural heat a great moving propelling power is produced at the down-cast over that at the up-cast.

Son: How is this moving propelling power applied in propelling along the current through the air-ways from the down-cast to the up-cast?—Father: In the following manner: the least minimum density and weight of the air is always at the up-cast, so that from the first yard the air becomes more and more dense, and the propelling force increases step by step; every yard in the

air-way along its route from stage to stage this propelling force increases, until the greatest maximum density and propelling moving weight is obtained at the top of the down-cast; or in other words, suppose we had two shafts near each other, one the down-cast, the other the up-cast—the length of air-ways from down-cast to up-cast, say 7,000 yards. At the top of the up-cast shaft a mechanical ventilator is at work, and by its great power the pressure of the air is diminished, say one pound; and I have no doubt that were it possible to detect the propelling force in every yard of route in the air-way, we should find this propelling force uniform from the first yard of air at the up-cast to the end of the 7,000 yards at the top of the down-cast shaft. The route from up-cast to down-cast being (as we suppose) 7,000 yards, and one imperial pound consisting of 7,000 grains, we should find one additional grain of propelling force in every yard of air all through the air-way, from up-cast to down-cast; this propelling force commencing with the first yard of air increasing one grain in force every yard, step by step, until it attained its maximum propelling pressure at the top of the down-cast shaft. In every yard of route, this elastic air requires the additional grain of propelling force to overcome the rubbing surface in its passage, and move along the current. The air then is obtained from the down-cast (you see) by a propelling force; not by drawing, pulling, or suction from a mechanical power at the up-cast.

Son: I well understand now how the natural heat of the mine produces a natural current; but, father, how does the furnace produce currents in mines?—Father: Just in like manner precisely as that produced by the natural heat.

Son: How does a ventilating fan employed at the up-cast, then, produce currents in mines?—Father: By reducing the weight of

the air thereat, and by such reduction the air swells and expands out, by which its weight is also diminished in the space occupied.

Son: The air being elastic, then, a reduction in weight swells and expands out the air in the same manner as swelled out by heat?—Father: They both produce the same thing.

Son: The propelling power then increases every yard, as before, step by step, along the whole length of the air-way, from the up-cast to the down-cast, as shown by the natural heat?—Father: The one is precisely the same as the other. I will now suppose the mechanical ventilator is removed and at work at the top of the down-cast shaft, and by its great power it propels a pressure as before of (say) one pound.

Son: But suppose the ventilating fan were employed at the down-cast to propel a weight of air downwards, would it then produce the same quantity of air?—Father: Just the same precisely as if employed at the up-cast.

Son: But if employed at the down-cast, will the fan have the natural heat of the mine to assist it?—Father: Whether employed at one or at the other, the natural heat assists both alike—if the dip is the same.

Son: But how does the fan at the down-cast produce the current?—Father: By its revolving force, it presses a weight on the air by which its density is increased, so that the greatest maximum moving propelling weight or density is at the down-cast, diminishing in density and weight towards the up-cast every yard it travels, step by step, through the whole length of the air-ways, from the down-cast, until it obtains its least minimum density at the up-cast. The propelling moving power, as before, increases from stage to stage every yard, all through the air-way, from the up-cast to the down-cast; or again, in other

words, if we were able to detect the propelling force in the first yard of air at the up-cast, we should find, as before, one grain of pressure, and also one additional grain of propelling force in every yard, step by step, from the first yard of air to the end of the 7,000 yards at the top of the down-cast shaft, where it would have attained its maximum pressure. So that there is the same law of nature for one as for the other, the propelling force in each case is always from the down-cast shaft; and when such is the case, that propelling force acts the same alike for each. Is not pressure and force the same in one as in the other, and the law of nature the same in one case as in the other? Judge ye. Such is my "peculiar" view.

Son: By pressure the air then is increased in density and weight, and also by a fall in the temperature.—Father: It is so. If air is produced for the workings of a mine, the density of the air, which is the propelling moving power of ventilation, must be increased much at the down-cast, to overbalance the pressure of the up-cast.

Son: Then you would increase the propelling power there as much as possible above that at the up-cast?—Father: It is the only way to produce a large quantity of air. When you have obtained the greatest possible density there, you have then obtained the greatest moving propelling power of ventilation.

Son: A mechanical ventilator may be employed then either at the one or at the other shaft?—Father: It is immaterial where employed; only obtain, I say, the greatest possible density there over the up-cast; for this, and this only, is the greatest propelling moving power of ventilation.

Son: Will density change in nature if a mechanical ventilator should be employed at the down-cast, because some people say a

ventilator will not produce the same quantity of air there, as when employed at the up-cast?—Father: Density is density, my lad, all the world over, and it is the same nature too by whatever power it may be produced and from what point or place it may be produced.

Son: If density change not in nature, will a mechanical ventilator, then, produce the same quantity of air by one pound of pressure added at the down-cast, as by a reduction of one pound at the up-cast?—Father: The quantity of air produced by each is precisely the same.

Son: You say, Father, that the atmospheric weight is 15lbs., and this weight presses alike on the top of each shaft.—Father: I say that.

Son: Then if you add one pound at the down-cast, will it not make 16lbs. there, to overbalance 15lbs. at the up-cast?—Father: It will, and by taking off one pound at the up-cast, it will make 14lbs. to be overbalanced by 15lbs.

Son: Will not the air be heavier from a density of 16lbs. pressure, than from a density of 15lbs pressure?—Father: Its density and weight will be one-sixteenth more.

Son: Yet the moving propelling force is the same in each case? —Father: Yes; the propelling power which moves the current along is precisely the same in each, but not the weight or density of the current.

Son: If density be one-sixteenth more in one than in the other, and you say the propelling power is the same for each, how will the same propelling power move two currents of unequal weights, and yet produce precisely the same quantity of air in one as in the other?—Father: Because there is one-sixteenth more air in the same area or space in one than in the other, so that, if the

motion were the same in the two, the largest quantity of air would be produced, you know, by that of the greatest density. So that if 15-horse power will produce a motion to the current of 16 yards, at a pressure of 15lbs., 16-horse power will produce the same motion to a current of 16lbs. pressure in the same space of time; the 16lbs. density requiring one additional horse-power, because air in it is one-sixteenth more than in the 15lb. density. Also, if the workings and air-ways remain in the same unaltered state, the "work" in the current's motion must be in proportion to the increased and the diminished velocity, its work then must be one-sixteenth more if propelled 16 yards than if propelled only 15 yards. If 16-horse power will propel the current 16 yards, 15-horse power must propel the same current 15 yards in the same space of time (when its work is one-sixteenth less), therefore, a 15-horse power will propel a current of 16lbs. density 15 yards, and it will also propel a current of 15lbs. density 16 yards, both in the same space of time, and produce in both the same quantity of air. If so, a mechanical ventilating power may be employed either at the down or the up-cast shafts, as the quantity of air produced will be the same in each.

Son: Do you think then that the extra quantity of air obtained by the extra density will be lost by a diminished motion of the current?—Father: The moving propelling power in this particular case, is governed by what may be called the mechanical law of motion. The extra quantity of air obtained by the extra density is lost by a diminished motion, yet the propelling power being the same in each, the quantity of air obtained in the two is precisely the same.

Son: Governed by the mechanical law of motion! I never heard before of currents of air in mines being governed by that

law.—Father: By this I wish you to understand, if the density be increased to one-sixteenth more, the amount of air in the same area of the air-way will be increased one-sixteenth.

Son: But if increased one-sixteenth, that increased density must, with the same motion, increase the friction to one-sixteenth more.—Father: Just so. But remember, if its density be increased one-sixteenth, 15 yards of the air-way will contain the same quantity of air in it as 16 yards of the less dense air, so that one current travelling 15 yards and the other 16 yards, in the same space of time, both will produce precisely the same quantity of air and alike the same friction.

Son: The quantity of air in both is just the same.—Father: And so is the friction alike in both, because if a certain amount of friction be in the travelling 16 yards in a certain space of time, that friction must be diminished to one-sixteenth less by travelling only 15 yards in the same space of time.

Son: Just so: I see it more clearly now.—Father: The amount of friction, increased by an increased density, is compensated for by the friction being diminished with a diminished motion of the current, so that the quantity of air produced is just the same in both for the same resistance.

Son: It will be so.—Father: The "same" quantity of air produced, mark you, whether increased or diminished in density, will then produce in motion precisely the same friction.

Son: I am a little surprised at that information.—Father: A given ventilating power then able to produce, mark you, a motion of the current, will produce the same quantity of air, whether that air be increased or diminished in density, because if less dense the current must be increased in motion to produce the same quantity of air in the same space of time, and that increased motion will amount the friction to the same thing.

Son : I hope you remember, father, that "Miner" has said that any increase of pressure or density at the down-cast is equivalent to a four-fold resistance or friction, while a decrease of pressure at the up-cast is tantamount to a proportionate reduction of such resistance or friction.—Father : If "Miner" had informed the public that a reduction of the pressure or density at the up-cast meant not only a reduction of friction, but it meant also a reduction of the "quantity" of air with it, and *vice versa*, an increased density of pressure at the down-cast meant not an increased friction or resistance only, but it meant also an "increased quantity" of air, and not an increased friction for the same quantity of air produced—had he said so, he would then have hit the nail on the head.

Son: How does "Miner" make the resistance or friction four-fold with an increased pressure or density at the down-cast ?—Father : You have asked me, my lad, more than I can answer, unless "Miner" explained himself thus :—If the air travelled not 15 yards, but 30 yards in the same space of time, then friction or resistance will be increased fourfold, and a fourfold expenditure of power will be required to overcome such; then we should have understood what he meant by a fourfold resistance.

Son : But if the current travelled 30 yards in the same space of time as it was 15 yards before, would not a double quantity of air be produced by it ?—Father : Just so.

Son : Then an increased density at the down-cast will not increase friction for the same quantity of air produced ?—Father : No, not one iota.

Son : And a decrease of density at the up-cast will not diminish friction for the same quantity of air produced ?—Father : It will not diminish it one iota. Therefore, one pound of propel-

ling power added will produce precisely the same quantity of air as a reduction of one pound. Why not? Density changes not in nature, but is the same in the two. Friction is the same in both for the same quantity of air produced, and the propelling power is the same, therefore the amount of air obtained must be the same if fixed at one shaft or at the other. . You know, as before stated, that a pound of pressure added or diminished is like the scales—one and the same.

Son: I am of your opinion; one will produce precisely the same quantity of air as the other.—Father: No person is able to say otherwise except they have had by experiment a ventilating engine at work at the up-cast and removed it to the down-cast, to know the quantity of air produced by each; and then the dip of the mine might also vary the quantity of air produced.

Son: Suppose you had a ventilating fan, at which shaft would you fix it?—Father: If possible, I would fix it at the top of the down-cast.

Son: But why; when the same quantity of air is produced at one shaft as well as at the other?—Father: I know the quantity of air for the workings would be the same, but there would be less danger of filling the workings with explosive gas.

Son: Filling the workings with explosive gas! Why, how can a ventilating fan fill the workings with gas?—Father: You know I have stated before, that gas is pressed or pent-up in the strata by the great weight of the atmosphere; therefore, to take away the weight, which presses the gas in would let the gas out, like letting out steam from a boiler, by taking the weight off the valve. Now, in case a ventilating fan were fixed at the top of the up-cast to propel air out of a mine, if the air passage between

the shafts suddenly closed up, every stroke of the fan would empty out that air which pressed in the gas, by which the mine would suddenly fill up with gas, and cause, no doubt, great loss of life.

Son: Do you think it would not fill, then, with gas, if fixed to force air into the down-cast?—Father: No; because every stroke of the fan would press a greater weight upon the pent-up gas, and give more time for the men to escape the danger.

Son: You say that ventilating furnaces are fixed in mines that the heat from them may expand the air, and produce a ventilating current through the underground workings?—Father: Yes. That object they are fixed for. As a current of air is produced by heat, the more heat you can cause the furnace to produce in the up-cast shaft, the larger will be the current of air obtained. A furnace should be fixed in the up-cast where the largest volume of air can be heated by it, as it will produce more air than if fixed in another place; therefore to fix it at the bottom of the shaft is much better than at the top.

Son: Some people think the top of the shaft is the best place to fix the furnace.—Father: If fixed at the top of the shaft much heat would be lost, and you know to have a loss of heat, which is the power of ventilation, would be to have a loss of air. When a furnace is fixed at the top of the shaft, all the air below it is left unheated; therefore, the larger the volume of the up-cast air you can heat, and more will be the pressure of the air from the down-cast. As before stated, heat expands air, and when expanded it is much less in weight; therefore, all that is required is to see that the furnace heats as large a volume of the up-cast air as possible, because, in proportion to the area of the volume of air heated and expanded, the weight of the air

in the up-cast is diminished, and the pressure of the air from the down-cast increased.

Son: I can see now, very clearly. To produce the largest quantity of air for the workings, you must fix the furnace in the up-cast, where it can heat the largest volume of air, for the greater the volume of light air produced and the greater will be the rush or pressure of air from the down-cast to occupy its place.—Father: Just so. Therefore, it is better to fix the furnace at the bottom of the shaft than at the top, whatever the depth of the shaft may be, as there is a much greater volume of air made light by fixing it there.

Son: Some people say that if you fix a furnace at the bottom of a very deep shaft, the heated air will become more and more cool as it ascends near the top, and thus becoming more and more dense, until at last it reaches its original condition of coolness, by which its ventilating power becomes diminished or destroyed.—Father: The expanded air may contract a little in passing away up the shaft from the furnace to the surface, but it cannot have a larger volume of contracted air than it would of cold below the furnace, if fixed at the top of the shaft.

Son: I see now. The air, below the furnace to the bottom of the shaft, may be said then to be all contracted; therefore, there would be more cool air by that way than the other. But if the furnace were fixed at the top of the shaft, would not the hot air rush out of the shaft to the surface with a speed much increased than it would if fixed at the bottom, and as the heat at the top of the shaft would be much higher in temperature, would it not propel away therefrom the cold air in winter, and by so doing produce a larger current of air for the underground workings?

Father: I will ask you a question or two, which I hope you will try to answer, and which will set you right to this question. Will not the air heated at the furnace rush away from it to a certain height, with the same velocity, if the furnace be fixed at the bottom of the shaft, as it would if fixed near the top? And if so, will not the air from the workings follow, or rush into the up-cast, with the same velocity, to occupy the place of the hot air?—Son: I cannot see that the velocity of the air from the furnace, and the velocity from the workings into the shaft, would not be as great if fixed at the bottom of the shaft as at the top.

Father: Then if the velocity would be as great, it would be much better to fix the furnace at the bottom of the shaft, because there would then be no loss of heat.

Son: Loss of heat? How do you show there would be loss of heat?—Father: Fix a furnace near the top of a shaft, and place your hand in it, and you will find the heat to burn you. That heat you feel is lost, but, if properly made use of, by the furnace being at the bottom of the shaft, it would change the cold and dense air in the shaft into warm expanded air, and by so doing, increase very much the ventilating volume, just as a balloon, if enlarged by the gas being expanded by heat, would ascend more rapidly, and also overcome a greater weight.

Son: I thank you for the information. I think, with you, the furnace will do more work if fixed at the bottom of the shaft, and, the deeper the shaft, the better, as in a deep shaft the heat is not lost at the top, before it has been made use of; a larger volume of light air is produced, and consequently, a much larger ventilating current is obtained.—Father: You will now remember, that the bottom of the shaft, and not the top of it, is the proper place for a furnace to be fixed to produce the most air.

Son: I do, and it requires, I see, much caution and care, and also a person with a good foresight, to prevent loss of life in mines. But I fully expected to have had, father, before this, a little conversation how gases are conducted by air through and around the workings of mines.—Father: It is my wish to impress on your mind, and also on every miner in the kingdom, things that will do good for years to come; therefore, as you have a knowledge how air is made to pass down into a mine, we will have a little conversation now, how air is made to pass several ways in and through the workings of a mine.

Son: Will you be able to show how air passed around Lund-hill workings, where 189 lives were lost, and at Risca, and at all those places where great numbers have been lost; and also show a better way to prevent loss of life?—Father: Yes, I shall be able to show the mode of ventilation of those places, and also a better way.

Son: Did you not show the mode of ventilation at Lund-hill which caused the four months' discussion in the public papers—and also a meeting to take place for discussion—between you and the late John Wales, Esq., viewer in the north of England? —Father: Yes: poor Mr. Wales, I was sorry to hear of his death. The north people lost a valuable man when he died; he was a man with a good knowledge of mine ventilation. He did not charge me with not showing properly the mode of ventilation at Lund-hill, or the improved mode, but he had a notion I had made an error in the non-fixing of a regulator; and at the end of the discussion it was stated, at the meeting, that Mr. Wales fixed the regulator in the plan *for* the manager, while I *showed* him *where* to fix it.

Several Modes or Ways of Ventilating Mines.

Son: You have a plan, I see, showing the mode of ventilation and working of mines. Where is this mode of ventilation adopted?—Father: In all mines where great loss of life has been caused by explosions.

Son: Was this mode of ventilation adopted then at Lund-hill, where one hundred and eighty-nine persons were killed by that dreadful explosion, and also at Risca, where more than one hundred and forty were lost?—Father: The plan you see shows the mode of ventilation on the south levels at Lund-hill; and the supposed place of the explosion was at or near the No. 24 (see plan); some supposed the place of the explosion to have been at the furnace, where the whole quantity of gas from all the workings passed through, as the power or shock of the explosion spread, and affected north and south at one time.

Son: Were there not many doors at Lund-hill? I understand there is always much danger where many doors are in mines?—Father: There were 52, just as many as there are weeks in one year. There are always a great number where this mode of ventilation is adopted.

Son: Do the arrows on the plan show the route of the air from the down-cast into and around the workings to the up-cast?—Father: Yes. You see the arrows show the passages of the air; it commences its route at No. 1, from there it travels on the south level to No. 2, from there to No. 3, from there back to No. 4, then onward to No. 5, back again to No. 6, from there onward to one of the working faces at No. 7, then it is conducted back to No. 8, from there to the face of one of the narrow workings at No. 9, it then returns to No. 10, from there to the

face of another working place at No. 11, then it returns to No. 12, it then enters the narrow working face at No. 13, and comes back again to No. 14.

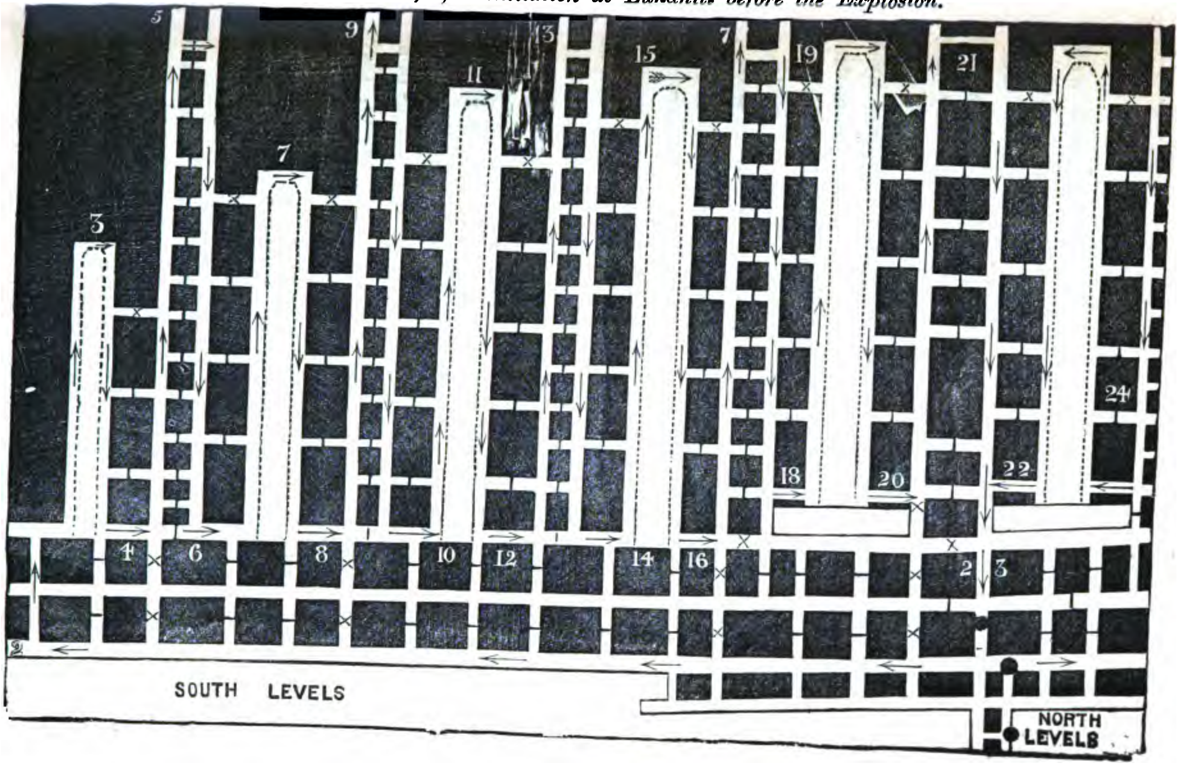
Son: Well, father, what a great route air travels by this mode of ventilation.—Father: Yes, and if the route extended as far from the down-cast through the workings to the up-cast, as one end of the river Nile is far away from the other, go it must, if only it can travel. There is no alternative with some managers but one continuous route, conducting explosive gases into every part of a mine.

Son: By passing air backwards and forwards into and out of one working place into another, there must be a large quantity of gas collected in the air, long before it discharges itself at the top of the up-cast. The air has yet to travel in and out from No. 14, to Nos. 22 and 23.—Father: At No. 22 (see plan) the gases accumulated in the air from all the workings in the north part of the mine meet the adulterated air from the south; at that junction the two currents join. Afterwards this large adulterated current passes through a blazing fire or furnace at No. 23.

Son: Is this mode of very ancient origin?—Father: It was first adopted by our great grandfathers in the early days of coal mining, and, I am sorry to say, handed down from one generation to another, as it exists at the present day.

Son: Is there no improvement to be made for the better and safer working of mines, and, if so, why keep to so great a life-destroyer?—Father: There are improvements in mine ventilating as well as in all other things, yet I cannot tell why the improvements are not adopted, unless managers do not wish to give up what was left them by their ancestors; or, their knowledge of mine ventilating may only consist in what was well known in the early days of mining.

PLAN No. 1, of Ventilation at Lundhill before the Explosion.



Son: If that mode of ventilating is adopted, we may well have, and must expect, great loss of life and property. I fear many lives have been lost by it.—Father: Many lost! The number is too great to be told. Your father was left in the world fatherless by it, and, from early life, I have had to make my way through the world without the blessing of a parent's care.

Son: I think, father, there was not so great a number of lives lost by explosions in the early days of coal mining as at the present time by the same mode. Can you tell why there was not?—Father: Because they had only limited means of getting out coal to the surface, they had only a limited number of works, they had only a limited number of persons employed in the works, and only limited means of ventilating them. Therefore, if they had only a limited number of persons, of means, of works, and of air, they had not so much gas in the air at the time of an explosion; that is to say, they had less air, and they had less works for the air to pass around; therefore, they had less explosive gas in the air when it ignited; and if less gas, the power of the explosion would be less when it did take place; and if the explosive power were less, and there was a less number of works, there would be a less number of persons lost at the time of an explosion. Therefore, by the same mode of ventilation, there was not so great a number of persons lost as now.

The Danger of one Mode of Ventilation, and the Safety of another.

Son: Air is conducted you say from one working part to another, clearing away the gas in its passage, from all places in its route?—Father: Some managers adopt that mode for the ventilation of mines (this is clearly shown by the Lund-hill plan), but it is neither safe nor profitable for miner or master.

Son: Why not safe and profitable?—Father: Because the mode requires many doors fixing in the tram-gates to impel air forward from one working to another, and to allow waggons to pass and repass with coal from the workings. It is unsafe, because, if one door be left open, all lives would be jeopardised; unsafe, because, if one place be affected, all the miners are in danger; unsafe, because explosive gas, conducted from all parts of the mine, will make a large quantity when collected; and therefore, the power of the explosion will be very great when it does take place; unsafe, because an explosion in any one part would affect the whole mine. There is also expense, too, in making and keeping air-gates large enough to allow the passage of sufficient area to take the gases away from all the separate working places; expense in making a great number of doors; expense in fixing them; expense in opening and closing them to allow waggons to pass and repass; expense in the furnace expenditure of coal, as a great friction of the air is caused by propelling a large quantity into and around so many working places; expense in destroying the whole workings if so large a quantity of gas becomes ignited; expense in day-wage work, &c., to make it all good after; and expense in making coffins for so many men who lose their lives by explosions.

Son: If air be conducted, then, from one place to another, it is not safe?—Father: No; as may be seen by the mode of ventilation adopted at Lund-hill, all the gases generated from the strata in the whole mine are collected in the air, as it passes onward from place to place, until the accumulation of gas becomes so great that an awful explosion takes place.

Son: I wish to see, father, a little clearer, as I do not understand it properly.—Father: Well, I will try again to make it more

clear. Suppose five separate groups of miners are working where much explosive gas generates, and each place requires 6,000 feet of air per minute for ventilating purposes. Now, if all the five currents of air make one, and the 30,000 feet pass through all the workings in one continuous route, all the five parts will be affected by an explosion, because all the separate working parts give off gas in the one current in which the explosion takes place, and, as all are ventilated by it, all are affected in the same manner. Among the first group of miners all the air enters, after which, it leaves that group or place and passes on to the second group, from them to the third, from them it proceeds to the fourth, and lastly to the fifth group. In the first group the men are well ventilated, and may be considered safe, providing that air and gas be not allowed to pass over a burning fire or furnace. In the second group they are less safe, from the fact that all the fire-damp discharged in the first group goes directly in a current upon the second group; then it proceeds to the third, from them it passes on, with the gases accumulated in its passage, to the fourth group; and then onward the adulterated current goes to the fifth group. Who, indeed, does not see that the miners in the fourth and fifth positions are liable at any moment to be destroyed by an explosion of fire-damp, unless the greatest caution be exercised? One part of the mine would be filled with raging flames, and the men scorched to death by the burning gases; in another they would be killed instantaneously by the expansion of the hot air and gas, or suffocated by the noxious gases which fill all parts of a mine after an explosion.

Son: There are other ways or modes of ventilating mines, you say, than the one adopted at Lund-hill? The mode of ventilation adopted there was that of conducting the *whole* current of

air around in one passage.—Father: Yes, there are other ways of ventilation. The air is conducted by another mode in the following manner:—One portion of it is conducted pure into one working place; after ventilating this place, and after the air has become impure with gases collected, then a fresh supply of pure air is mixed with it to ventilate another place; and in like manner this mixture of pure and impure air takes place alternately when each working place is ventilated; and so the one air current passes on, with all the gases in the mine accumulated in it from every working part, until it discharges itself at the top of the up-cast.

Son: Will plan No. 2 show this mode of ventilation, by which working-places are supplied with a mixture of pure and impure air?—Father: Yes. The points of the arrow on the plan show the passage of the air through the workings. When the air first enters at the down-cast, it passes direct to No. 7 working place; after ventilating this place it is supplied with a portion of fresh air for the ventilating of No. 6 working place, the mixture taking place at the letter S (see plan), and in like manner, all the other working parts are ventilated with a mixture of pure and impure air; the mixture takes place for all parts at the letters S S.

Son: Is this mode adopted for the safety of miners?—Father: Those persons who adopt such a mode believe it to be for the good and safety of miners, and economy for the employer.

Son: By this mode, air-gates, I see, do not require to be as large as those where the whole quantity of wind passes in one current through the workings, like Lund-hill; therefore, the expenditure will no doubt be much less.—Father: The mode would be more economical than if the whole of the air passed around the workings in one current; but the danger of loss of

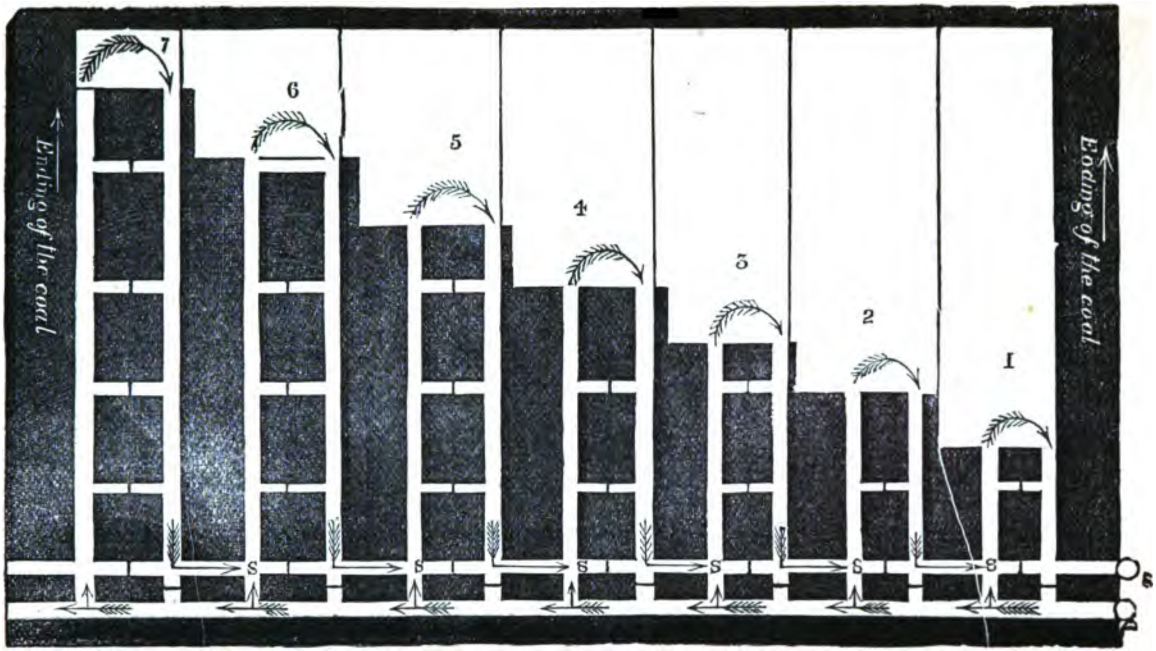
life by an explosion would be the same as that of ventilating by one current.

Son: It is clear that an air-gate will not require to be so large, for, say 6,000 feet, or 12,000 feet of air to pass, as for 50,000 or 60,000 feet, and, therefore, the expenditure will be much less. But why is the danger of loss of life the same?—Father: Because this mode of ventilation neither divides air nor gas, the gas being conducted in the same way as in the other method I described from one working part to another, in one continuous route, so that all the gases in the mine become formed, or accumulated, into one large quantity; therefore an explosion in any part of the mine would ignite the whole quantity of gas, the power of such an explosion would affect all parts where the air passed, and cause great loss of life.

Son: The mode of ventilating mines by one continuous route is caused, you say, by fixing doors to propel air forward from one working part to another; I wish to know, then, how this mode of supplying the workings with a mixture of pure or impure air is accomplished?—Father: It is accomplished by fixing *regulating* doors in the air passage. Air, you know, will always rush by the nearest route from the down-cast to the up-cast, and regulating doors are fixed in the air-passages to prevent the great rush of air, and propel a portion of it into, and around, the longest routes which would otherwise be left without air. The doors are fixed in the openings *between* the in-take and return air-passages, at or near the letters S S. (See Plan.)

Son: I shall be glad to know, at a future day, why air rushes round the nearest workings, and the longer route of workings are left destitute of air: but how, father, are regulating doors fixed in mines?—Father: They are fixed in those air-passages through

PLAN No. 2.—*The Impure Air supplied with Fresh Air.*



which the air rushes with great velocity, in order to take off, or propel, such quantities of air as are required for other workings, and they are so fixed as not to fill the whole space of the air-passage, but open spaces are left to allow a proper quantity of air to supply other working parts of the mine, dividing the air, but not into separate distinct currents.

Son: Very well; but what other ways of ventilation are adopted?—Father: Another is, that of conducting the air into the workings similar to the plan of ventilation adopted by the late John Buddle, Esq., viewer in the North of England.

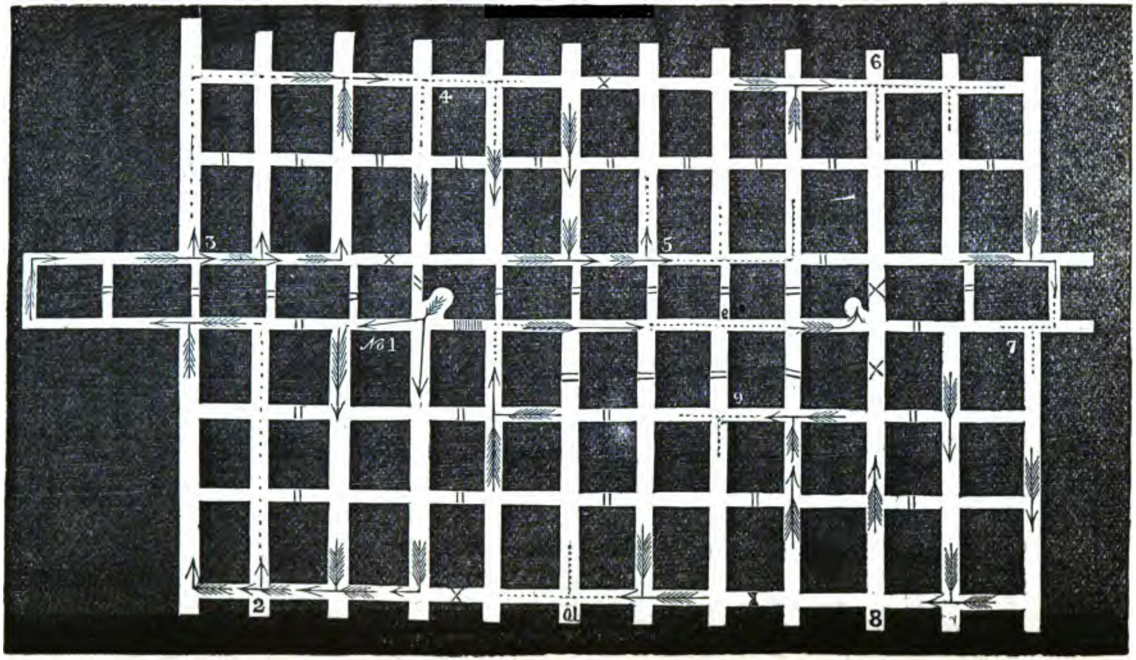
Son: Was Mr. Buddle's plan considered to be a safe mode of ventilation?—Father: I believe it was much thought of in his day; yet it is not a safe mode of ventilation.

Son: What was the mode he adopted?—Father: It was one similar to several modes of ventilation I have seen adopted in mines at this day, and which many managers call dividing the air; yet it is not what may be called splitting of it into distinct currents. This mode of ventilation is to divide the air into separate parts, for separate groups of miners; after which, all those separate parts of air return into the same current again from which they separated. Then again, this one current of a mixture of winds is divided a second time for more groups of miners; after this all the separate winds form one again, and this one mixture of wind passes on further into the extremity of the mine until the said one current requires dividing for other workings of the mine, and so the same is allowed to divide or separate into as many parts as workings, returning and forming one wind again after being divided. This mode of ventilation cannot be properly called splitting the air, because the air is allowed to return back into the other portions of the air from which it separated itself,

and no working part has a separate distinct wind from the others, as each division is a mixture of winds from the others, with gases collected from the same in each wind. Therefore, as the air is allowed to spread in and through the workings, every part would be affected by an explosion therein; for the gases collected from all parts would be mixed in the said wind in which the explosion might occur. This being the case, the flame of the ignited gas would fly and spread in and through the workings of each part like the electric fluid, carrying death and destruction in its passage. By this it will be seen that this mode of ventilation does not divide or diminish the explosive power (gas), as the explosive gas would be like a combustible train, and if ignited in any part, would fly through and around all the parts where it circulated. Plan No. 3 is, I believe, a representation of Mr. Buddle's mode of ventilation: by an inspection of it, it will be seen that the air separates ten times in its passage through and around the workings, and the current of air which ventilates the whole mine is formed into one wind as often as it is divided, by which all the gas generating from one strata through the whole mine is collected into one vast quantity. As to the number of times the air is separated in its passage through, from the down-cast to the up-cast, see Plan at Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10. This mode of ventilation, if called a splitting of the air, is not a separate distinct dividing of the gas.

Son: Was this the mode of ventilation you alluded to in your reply to a person in the "Miner," who requested you to inform him of the meaning of split winds in mines?—Father: This plan does not show the mode of splitting air, yet it is the one I alluded to in my letter.

PLAN No. 3.



Son: Let me see the letter.—Father: Here it is; it will give you a knowledge between this mode and that of ventilating by separate distinct currents.

THE LETTER.

Sir,—In your "Notices to Correspondents" of last week's impression (January 2), I am requested to inform a "Constant Reader" the meaning of "Splitting" the air.

My object through life has always been (and I hope will, until my work on earth is finished) to try to better, if possible, the miner. When I speak of mine ventilation, it is from a practical knowledge of seeing and doing the work, and not from a knowledge only of theory, reading and hearing. When I speak of air splitting, I mean separate, distinct currents, and not that kind of splitting which is similar to that which takes place when the wind blows on the surface against a builing, the wind being separated by it, and afterwards mixed again; and so the wind is divided and mixed in passing and repassing every building. The above is similar, I say, to the splitting adopted by some managers. They allow the whole of the air to pass in one large current, until one portion of the air is propelled by the great friction of the air around one part of the mine, and another portion around another part; and so the said air is allowed to split or divide as it rushes through the mine into as many parts as are working, returning and forming one wind after it has been divided; therefore, it is not a separate, distinct current or wind, but a mixture of wind, with gases collected in the wind from all parts. This mode, as before stated, divides neither air nor gas, as gases from all parts are mixed in the one said current; therefore an explosion by the same would affect all. But, I am asked: What is meant by the splitting of the air? I would also ask: What amount of air can be produced for the whole workings of a mine? Can 20,000 feet, 40,000 feet, 60,000 feet, 80,000 feet, or 100,000 feet be produced per minute? Be that amount less or more, do not propel, in one current, the whole of it around the workings of a mine? Divide, split, or separate the whole into "distinct currents," or parts, of say from 5,000 to 7,000 feet of air for each current, after which, if five, ten, fifteen or twenty miners are getting coal in one

district of the mine, supply the said number of miners with one current, say 6,000 feet of pure air direct from the down-cast; after which, conduct the said current direct from the said miners to the up-cast, and not ventilate other workings with it afterwards. Supply another current, say 6,000 feet, of pure air to miners working in another part of the mine, conducting the said current as before direct from the down-cast to the working parts, and therefrom to the up-cast, and so on in a similar manner supply each party of miners with distinct currents.

If the discharge of explosive gas be too great in the workings for, say, 6,000 cubic feet of air, to dilute and render it harmless, reduce the number of workings for the said amount of air, or make two divisions of the said number of works, so that the gas may be divided and rendered harmless by each separate current or division of air—that is, regulate or reduce the number of works to be ventilated with that air in proportion to the quantity of gas generating in such works. But it may be asked, how or by what way is 5,000 or 7,000 feet of air to be sent or propelled into the workings in separate quantities, as the distances for the air to travel are not alike equal in length, the distance being much greater around one number of miners than around another; and such being the case, more than 6,000 feet of air may pass into and around one working part, and much less than the said amount around another part; by this, one part will have a superabundance and another a deficiency of air. In reply to the above—"Such, doubtless, will be the case if the air-gates be large enough to allow a larger portion of the air to pass into one part than into another." All that is needful in this case is simply to enter the return air-gates of those parts from which a little air is required to be taken, and by fixing a regulator therein, each division of air may be so regulated as to allow only a sufficient quantity for each working part. Also the impure air, in its return, may come in contact with the intake pure air of another division; if so, an overthrow similar to a bridge over a canal, will be required at such part or place, the overthrow so constructed as not to allow a mixture of the two currents. Ventilate the workings of a mine as above stated, and you will have separate or split winds therein, and no explosions like Risca, Lund-hill, and many more such like.

Yours faithfully,

St. Helen's, Jan. 11. WM. HOPTON.

Plan No. 4 is a representation of this mode of splitting the air into separate distinct currents, yet there are more plans which show this mode of ventilation.

Son: Then an explosion, as shown in Buddle's plan of ventilation, and also that at Lund-hill, would cause great loss of life because all the gases accumulated in the air pass from one working place to another in one large quantity?—Father: Such is certainly the case. The object of ventilation, namely, the preservation of life and property, is altogether lost sight of. The mode of ventilation has always been to send around the workings a large current of air to take a large quantity of gas away; but the object of ventilation, to prevent loss of life and property, should be to divide this large production of gas by ventilating the working where it discharges separately. Divide the power (gas), and the effect produced by an explosion would be very little. If you had to work in a room where a ton or barrel of gunpowder was exposed to a great number of people, and at any moment an explosion might take place, you would say, remove the gunpowder, or divide it into pounds, so that the effect may not be very great if a part should become ignited.

Son: I see the cause, father, now, of people often saying after an explosion of fire-damp, that such and such a mine was (where great loss of life has been caused) well ventilated; it was ventilated well with impure air.—Father: No mine ventilated with impure air can be called a well ventilated one, if the air passing through be ever so great. I do not doubt for a moment but (where great loss of life and property was caused), they have had much air, but it was impure. No one will doubt that, for the explosion which caused the loss is the witness, as an explosion cannot take place in air where gas is rendered harmless.

How the Power of an Explosion may be diminished.

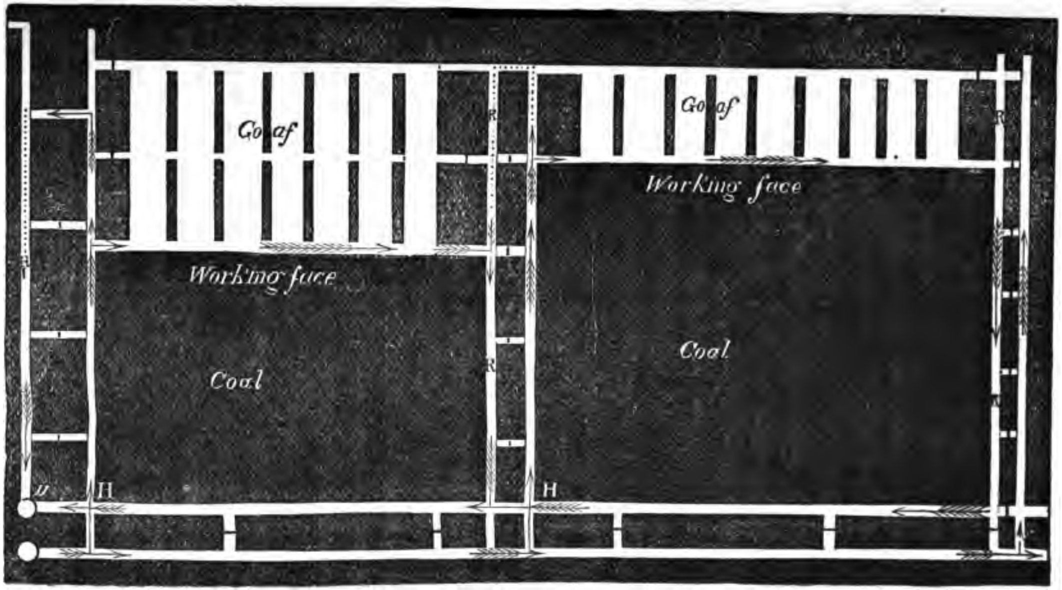
Son: The best mode of ventilating mines, then, for the safety of miners, is that of splitting the air into parts, by which each group of miners is supplied separately with their own pure air direct from the down-cast?—Father: Yes, pure air is split to allow each working part its own proportionate quantity, in proportion to the accumulation of gases in each part.

Son: I see, father, on plan No. 4, several letters, R and H, what am I to understand by them?—Father: An overthrow is fixed in those places where you see an H, and a regulator at R. An overthrow is so fixed as to prevent a mixture of pure and impure air, and is so constructed that one current can cross over. The other regulators are also fixed to supply each separate working-place with a due quantity of air, in proportion to the accumulation of gas; if no regulators were fixed, one part would receive (in proportion to the distance) more air than another.

Son: Then explosive gas by this mode is prevented from accumulating in large quantities?—Father: Yes; the object of splitting is to accomplish it. If one wind pass around, say, four working parts, explosive gas will accumulate in the air, from all the parts, so that four times more gas will be in the current of air than there would be if only one-fourth of the air ventilated one part or place only. Therefore, in proportion to the quantity of gas, so is the power of an explosion.

Son: Then what you wish me and others to understand is this; if, say, one hundred feet of gas accumulated per minute in each working part or group of miners, you would not ventilate, say, four parts with one great current of air, as by so doing you would have four hundred feet of gas in it, but you would venti-

PLAN No. 4.



late each part or group separately, because, by so ventilating, you have only one hundred feet of gas to explode, and not an explosion of four hundred feet; therefore by reducing the gas to one fourth, the explosive power is reduced four-fold.—Father: Such would certainly be the case. If loss of life and property must be prevented, splitting of the air for the ventilation of mines must be adopted, because great loss of life is caused by igniting too large a quantity of gas. Split the air for workings into parts, and you divide or split the great explosive power (gas) with the air—that is to say, take the gas away, and you take that power away which causes such loss of life.

Son: Then if the workings of four groups of miners are ventilated separately, and if gas ignites in one, you prevent the explosion spreading to the accumulation of gas in the other three groups, and therefore prevent loss of life; and you also reduce the explosive power in those parts where gas explodes by three-fourths.—Father: To ventilate a mine by splitting the air, several objects are accomplished, by which loss of life and property is prevented. 1.—The explosive power is reduced to one-fourth less than it would be if one large current of air ventilated all the four parts; and by the power being so reduced, the men may escape from the exploded part without loss of life. 2.—As the explosion is confined to the one particular part where the gas ignites, you prevent loss of life in the other three parts, because no explosion takes place in them, as the route of the explosive power can only spread around one part, and not around all the four. 3.—The quantity of choke-damp produced by an explosion is reduced by this mode of ventilation to one-fourth. You know in proportion to the quantity of explosive gas ignited, so is the quantity of choke-damp after an explosion; therefore,

when the quantity of choke-damp (which destroys the life of the miner) is diminished, we must expect the loss of life to be diminished accordingly. 4.—The danger to a person's life is reduced fourfold, because those employed in other parts do not jeopardise their lives by working in the gas which has passed around other places. 5.—This mode prevents doors being blown away, because few are required, and the power which destroys them is reduced, therefore the danger of loss of life by the same is reduced. 6.—This mode supplies every working part direct from the down-cast with pure air, therefore, when an explosion takes place, the fresh air enters the exploded part shortly after, and loss of life is often prevented. But such is not the case by the other mode of ventilation; lives are lost for the want of fresh air.

Son: Is there anything said, father, against this mode of ventilation?—Father: Yes, much is said against it, and that, too, by men professing to have an extensive knowledge of mining.

Son: What is said?—Father: It is said, if one wind does not ventilate—say all the four working parts—you take the air from the fourth part by ventilating each part separately, and, by so doing, you may not have a sufficiency of air for each part.

Son: Well, but they should also remember that if the three divisions of air do not pass around the fourth working-place, the gases generating in the said three divisions also do not pass into the fourth working part, and therefore, if you take air from the said part, you also prevent gas from going to it. And there is more danger in not having a sufficiency of air to take a large quantity of gas from a great number of works, than not having a sufficiency of air for a less quantity of gas. There was sent

through the workings at Lund-hill a large quantity of air to take a great quantity of gas from many parts, but the large current was not sufficient for the quantity of gas, and awful was the result. At Burradon, Risca, Cymmer, the Oaks, &c., a large current was also sent through the mine to take a large quantity of gas from many parts; but the current of air was not sufficient, and the result was accordingly. If gases generating in the the workings of one group of miners cannot be rendered harmless by a certain quantity of air, gases generating in the workings of four groups of miners will not be rendered harmless by four times that amount of air. Therefore, as no one can show great loss of life by splitting, it is better to adopt that mode for the safety of miners.—Father: I think you will be able to show the public shortly the best mode of ventilation. Yet others recommend for the safety of miners, stoppings, doors, and overthrows to be strong enough to withstand the shock or power of an explosion, because stoppings several feet thick are blown away by the power.

Son: It is very strange, father, for those professing to have much knowledge of mining, to talk in such a way. Divide, reduce, or diminish that power which blows the stoppings away, and you prevent miners from being blown away. It is of little use making stoppings, &c., to withstand a greater shock, if a miner's body is not able to withstand it. If such people were in a mine when an explosion takes place (if spared to get out), they would say—"Unless this power be reduced, I will not be found here again." But, father, how is this mode of splitting the air and gas, by which every working part of a mine may be supplied direct from the down-cast with pure air, accomplished? —Father: This mode is accomplished by fixing regulators and

overthrows in a mine. Overthrows are similar to a bridge over a canal, over which passengers go to one end, and vessels pass through at the other. As the air passes pure from the down-cast into the workings of one division of miners, it may come in contact with the return impure air of another division; and, as the impure air is required to cross or go over the pure, an overthrow is required at such place, to cause one division of air to cross the other—such crossings are so constructed as to prevent a mixture of the two currents. Regulators are also fixed in the nearest return air-gates to the upcast shaft, to regulate the proper quantity of pure air in proportion to the gases generating in each part, by which one group of miners, with a deficiency of air, will be supplied with a sufficient quantity, or will take a little from those parts which have a superabundance.

Son: You say the mode of ventilating mines by splitting the air into separate distinct currents is much better both for the safety of miners and economy of employers. I shall be glad to know, father, why it is not adopted. Is it because people think mines will give off more gas by this mode of ventilation?—Father: No; a change in the mode of ventilation, you know, will not cause an extra quantity of gas to discharge in mines, as the discharge is the same for one mode as for another.

Son: Yet people with no proper knowledge of mine ventilation may think there is less space or room in the air-passage by the mode of splitting into separate distinct currents, than there would be if all the divisions of wind formed one wind, to pass in one current the whole quantity through such air-gates, and this is their objection.—Father: If many divisions of air form one large current, and pass in one continuous route through one air-gate, space will be required in the passage accordingly, or the

same quantity of air cannot be produced by one mode of ventilation as by the other; therefore, as there is more room for the air (in the passage) for separate divisions than for many, it cannot be the cause why such is not adopted.

Son: Will the explosive power be greater, and cause this mode not to be adopted?—Father: No; because dividing the air into separate distinct currents is reducing the gas, and reducing the gas is reducing that which causes the power of an explosion.

Son: Is the production of pure air for the workings much less by this mode of ventilation, and is that the cause why it is not adopted?—Father: No, because this mode will produce a much larger quantity of air; yet air will not be forced to pass through the workings in one large current, but be distributed in quantities in proportion to the discharge of gas in each working part, and there will not be, as before, a large mixture of impure air. Therefore, this large quantity of pure air produced is caused by diminishing the friction, by allowing a large space in the air passage.

Son: Some may have a notion, father, that if one large current of air ventilates—say six divisions of miners, one-sixth part of that current cannot ventilate or do one-sixth part of the work as well as all the air does all the work?—Father: That cannot be the objection, because one-sixth part of the air will do one-sixth part of the work much better; for the impure air by this mode is conducted away to the up-cast, and not mixed with the pure air to occupy its space in the air-passage, and impede its progress through the workings by taking up the space it ought to have.

Son: If one large current of air ventilates, say six divisions of miners, and this large current is, after ventilating the work-

ings, very impure with gases, do you think that is the cause why splitting of air is not adopted?—Father: No, that cannot be the cause; as the quantity of gases conducted in and around the workings is much less by this mode than by others. Nearly one-half of the gas of the mine, by this mode of ventilation, does not enter the workings, but is conducted away to the up-cast. By the old mode of ventilation, the accumulation of gases in the returns of one part pass into the workings of another part, but not so by the new mode. If a mine cannot be worked with safety by the new mode of splitting, it cannot be worked with safety by ventilating many divisions of miners by one large current; because, if there is only one-sixth part of the air in a division, you have only one-sixth part of the workings to ventilate with that air, and the gas accumulating in the returns, as before stated, is conducted away from, and not into the workings.

Son: Is it not adopted because the distance is not the same for air to travel by this mode as the other?—Father: No, that cannot be the cause, as air will travel a short distance much better than a long one. To split the air into parts and ventilate each working part separately, one division of air will only have to travel around one part, and not around six; therefore, air will travel around one much better than around six, as a person will travel one mile with a load much better than six.

Son: Is it adopted because there is not the same need for the furnace to produce ventilation by one mode as the other?—Father: I cannot see that reducing the work of the furnace will be any inducement for not adopting the mode, but a very strong one why it should be adopted; because if air has only to travel around one part and not around six, and also one division of air occupies the same space in the air-passage as six, the friction of that air

will be very much diminished; and if the friction is much reduced, the furnace will produce for the workings a larger quantity of air, because the quantity of air produced by a furnace is always in proportion to the friction overcome by it. Diminish the friction, and the furnace will (in proportion to it) produce you a larger quantity of air.

Son : Is this mode not adopted because falls of the roof may affect the air-passage, and not so by the other mode?—Father: There is more danger of falls affecting the air-gates, by ventilating many workings with one large current, than by ventilating each separately, because, if there is not room for one division through the fall there cannot be room for six; and if not room for one division what would become of the men if all the six divisions of air, forming one wind, were required to pass through the obstructed part.

Son : Is it because this mode of ventilating mines cannot be adopted where any other plan of working out coal is used?—Father: No, that cannot be the objection, because in the working of mines there are always two or more gate-ways for every working part, as they cannot pass air both in and out with one. One gate-way is for air to enter, and the other to return; therefore, in its return, you conduct the air direct to the up-cast, and not pass it around other workings. You ventilate all other parts in the same way.

Son: Do you think this mode is not adopted because the number of workings is thought to be too many for the air to ventilate if split into parts?—Father: If one wind in one continued route will ventilate any number of works, the same wind will ventilate the same if split into divisions, because nearly one-half of the gas is conducted from and not into the

workings. By it the explosive power (gas) is reduced. The extent to which the explosion will spread is reduced, and the quantity of choke-damp is also reduced.

Son: Do you think they object to the mode because too expensive?—Father: It is not so expensive as the other modes, because there are fewer doors to make, to fix, to open and close when fixed; there is less expense in trappers (door boys), less expense to make an air-gate for one division than for six, and less expense in coal for the furnace, as the friction of the air is reduced.

Son: Well, father, I am not able to ask any more questions why the mode of ventilating mines by separate distinct currents of air is not adopted. You clearly show there is no cause why great loss of life should take place in mines, as the mode is both better for the safety of the miner and for the economy of the employer. Where a great number of works, discharging a large quantity of gas, are ventilated with a large quantity of air, I cannot see how, if a great loss of life is caused, the result can well be called accidental; because how can anything be called accidental when it is well known and seen before it takes place? They know if the mode is adopted it will cause great loss of life; yet it is adopted. Then, I ask how can the loss of life be accidental?—Father: There is no reason for such loss of life, and I fear no contradiction in so stating; it is time to stop all such life-destroying modes. We have too many of those well-ventilated mines exploding, and too many lives lost by (it is said) tobacco-smoking, or gas becoming ignited from a flint stone.

Son: I presume, father, if an explosion took place, you would not spend two or three days inquiring at what part of the mine the gas ignited, the extent to which the explosion had spread,

the powerful effect produced by it; whether it was ignited by a candle-blaze, a safety-lamp, a match, a tobacco-pipe, or a spark from a flint-stone; who ignited it, or by what means it became ignited; but how was it that such a quantity of gas was allowed to accumulate, and what means of ventilation had been adopted to prevent its accumulation?—Father: I think it would be much better to inquire how it was that such a quantity of gas was there, for had it not been there, no one could have ignited it. Remove the cause and the effect will cease.

Son: You say, father, the mode of ventilating by separate distinct currents may be adopted where any plan of working out coal is used. As you have been an underground manager many years, I wish to know, if in those mines under your charge, you have always adopted the mode of separate distinct currents of air, that is, changed from the old to the new mode of ventilation?—Father: I have had charge of several mines in Yorkshire and Lancashire, and in those mines which gave off much explosive gas, I have always changed from the old mode to that of separate distinct currents, and by so doing prevented, I believe, much loss of life and property.

Son: You have had no loss of life by explosions,* you say, in the mines under your charge; but you may had have little or no explosive gas in such mines, and that may be the cause why you have had no loss of life.—Father: Like others, I have had mines varying in the quantity and quality of the gases discharged, yet few have had, I think, more explosive gas to contend with. I

* Since this work went to press one person has been lost by going into another person's working place, with a naked light, before it was examined. He died in 13 days after being burnt. The power of the explosion was not sufficient to extinguish naked lights 30 yards distance from the place of the explosion. Another person died by an explosion in 1872. He saw the danger signal, yet passed over it with a naked light. The Jury said, had he lived and another person had died, he would have been condemned for manslaughter. They were the only two lost by explosive gas under W.H.

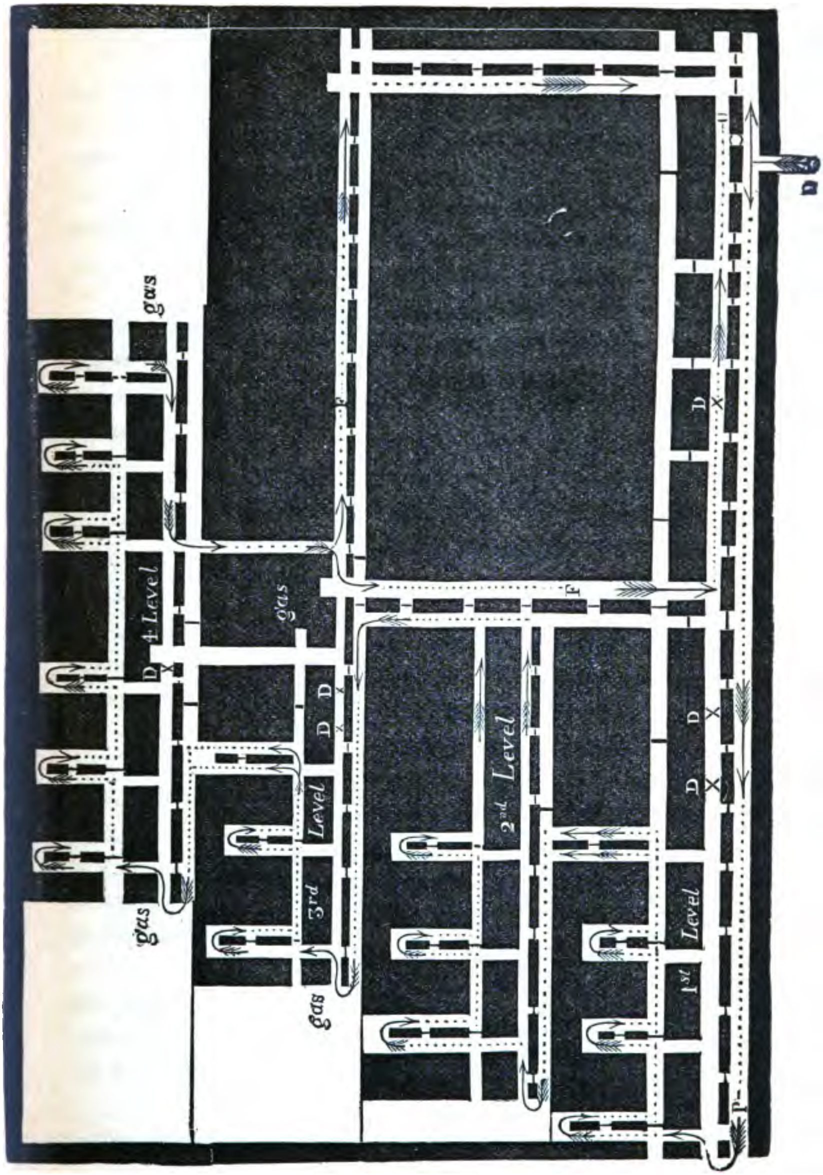
have seen men affected and struck down by it in a moment's time, and seen it ignite and crack often in the safety-lamp. But my method of ventilation to prevent loss of life and property has always been—1. To obtain all the air possible for the workings.—2. Not to have more works to ventilate than pure air can reach.—3. To ventilate those workings generating much explosive gas separately.—4. To conduct explosive gas away from the miner, and not to him, because there is a right and a wrong way of conducting air and gases from the workings of a mine. To illustrate my meaning, suppose a number of chemical works were near a large population, who became affected by breathing impure air at such a time as the wind blows from the works towards them. But in case a change in the wind takes place, by which the noxious gases are blown away in an opposite direction; if the force or velocity of the winds be not one-twelfth of that which blew the gases to them, they will by this change of the wind breathe a purer atmosphere, as no gas can come against the wind, be its velocity ever so small. And so it is in the ventilating of mines, if air be properly conducted around them. Miners' lives are often jeopardised by managers conducting the whole of the gases into and upon the tram-roads and waggoners.

Son: When you were first engaged at a Colliery in St. Helens, you adoped, no doubt, separate distinct currents of air.—Father: Yes, I did; because I found in one mine much explosive gas generating. The men had to work with red-hot safety-lamps. The discharge of gas was so great that coals were lost, as a safety-lamp could not burn, nor the place be approached with one; and in the waggon roads, gas often ignited in the safety-lamps hundreds of yards from the working faces. As this state of things was so bad, I drew a plan to show my employer it was

possible to make a change in the mode of ventilation, and adopt for the workings separate distinct currents of air; and having a good knowledge of mines and mining, he was at once convinced it would be much better for the safety of the men. He ordered its adoption, fearless of expense, but I assured him it would not cost £3.

Son: I shall be glad, father, to see the way by which coal was worked out, the mine ventilated, and the improved mode you adopted.—Father: If you wish to change the mode of ventilation, it will not do at all times to change the mode of working out coal, in order to enable you to do so, as another mode of working may not answer for the seam of coal; therefore, in making a change in the mode of ventilation, you have often to contend with difficulties, because you cannot make air-gates in places you wish. I may also add, if a person has not got in him the ability to make a change in the mode of ventilation, without changing the mode of working out coal, he is not a proper person to take charge of the underground workings of a mine. In the mine in question I had to make a change in the mode of ventilation, and not in the way of working, which may be seen in the two plans, Nos. 5 and 6, before you. Plan No. 5 is a representation of how the mine was worked and ventilated when I first took charge. Plan 6 shows the same mode of working the coal, and the change I adopted in the mode of ventilation. You will see in plan No. 5, that the air enters the down-cast, and passes on to the lower level to the letter P, a distance of nearly 800 yards, after which the air passes forward through and around all the workings in one continued route, and in one current.

PLAN No. 5.



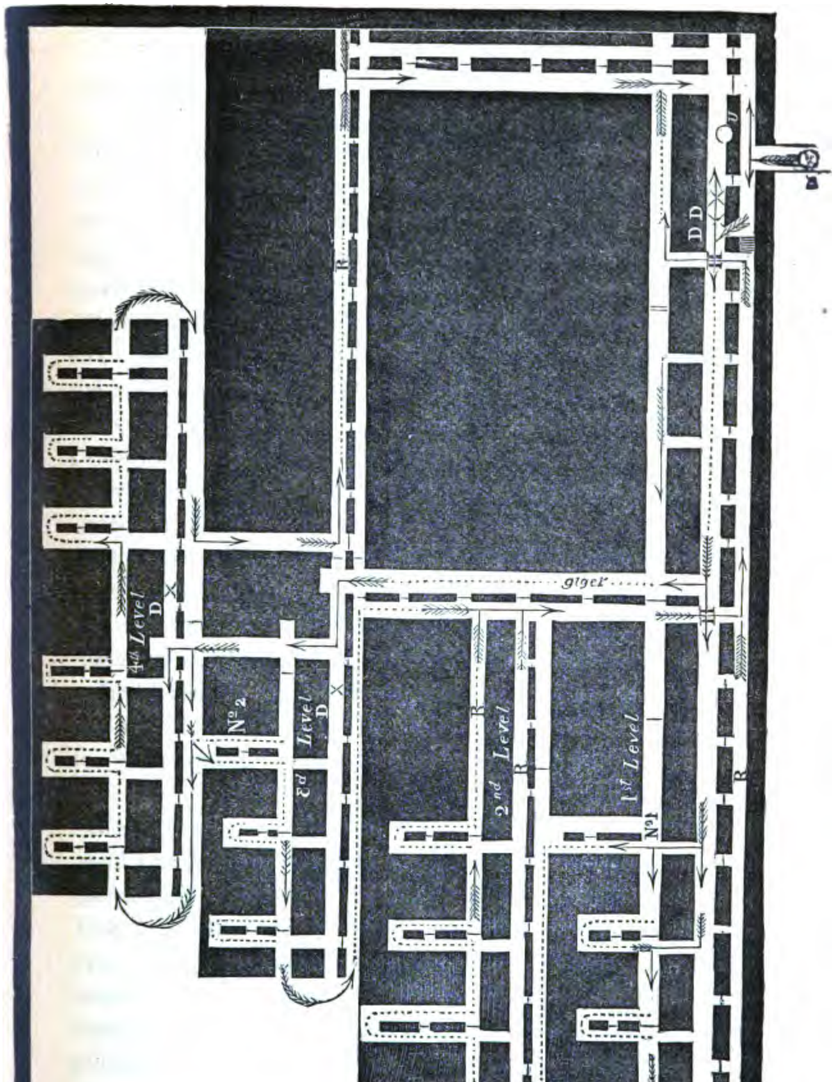
Son: Very good. But what am I to understand, father, by the other letters I see on the plan?—Father: The letters D D are for doors. F F show where gas often exploded in the safety-lamp. You see the third and fourth levels. Well, in those levels the discharge of gas was so great that a safety-lamp could not burn, and the coal had to be left until the change in the mode of ventilation was adopted.

Son: In looking over plan No. 6, I see, father, that pure air passes out of the lower level into the waggon road, and onward to the jigger, where the air divides for the third and fourth levels, by which one division takes place at No. 1, and at No. 2 another division of the air takes place, so that each level, I see, is ventilated separately, as fresh air enters from the down-cast to each level working. Therefore, each level will only have its own gas, and not the fourth level have gas conducted from the first, second, and third levels.—Father: Such is the case. By this mode of ventilation the gases discharging in one working place do not pass into the workings of another, and you may blow into the workings pure air on the waggon roads, and not as before, impure air, as the impure air is conducted from the workings on roads not in use for waggoners.

Son: I presume, father, an air-crossing is fixed at the letter H, and also a regulator at the letter R, and doors at the letters D D?—Father: You are right; such is the case. I only show the plans to give you a knowledge which of the two ways of ventilation is the best. By one way coal was left, but not so by the other.

Son: Did you clear the gases away, after your plan was adopted?—Father: Yes; the men were able to work with naked lights after, in nearly all the places; and we also got out the

PLAN *No.* 6.



coal, which had been left where a lamp could not burn, or be got near, before the change.

Son: No doubt the men would be very glad when the change took place.—Father: It may be well to relate what took place at the time. You know that miners have a notion that employers seldom change their managers for the better. I was one of those who they thought made things no better; so when the change took place, up came the men out of the pit, and stated to the master that the fire (explosive gas) was in their places. The fireman being there at the time, and hearing what they had got to say, and having just come up the pit from the workings, said to one—"Well, Jack, what's thou come up for?" Jack:—"I reckon we've come up for fire." Fireman:—"Is there any fire in thy place?" Jack:—"No, but there is in others, I suppose." So he (the fireman) said to another—"Well, Bill, what's thou come up for?" Bill:—"I have come up for fire, like others." Fireman:—"Is there any fire in thy place?" Bill:—"No; there is no fire in my place, but there is in others, I suppose." So the fireman questioned Ned, Tom, Bob, Sam, and Charley, all in a similar manner, and each was able to work in his own place with safety, but had come up because "others could not work for fire."

Son: Did you say anything to them, father, all the time?—Father: I allowed them to say all they had to say, as I knew that truth would always make its way. Then their object having been seen by the master, and by every person there, I said, "You know, men, before the change took place, you had to work with red-hot safety lamps, and some of you had to give up working in your places, because the discharge of gas was so great that a safety-lamp could not burn, and coal was lost, because

the quantity of gas was too great to allow you to get it; and gas often exploded in the safety-lamps hundreds of yards from the working faces in the waggon roads. Therefore, I wish to prevent the loss of your lives, because I also may be lost, if you are." If an explosion had taken place, a great number, no doubt, would have been lost.

Son: Did you say anything more?—Father: The master said many heads had many minds; therefore, it would be well for them to find a better mode of ventilation, and, no doubt, I should be glad to adopt it. I assured them I would adopt it with great pleasure.

Son: Did they find, then, a better mode of ventilation? —Father: No. I offered two pounds to any person who would draw a plan of ventilation as good for their safety as mine; but home they went, and I cannot say whether or not a fight took place on the road, as one said, "I should not have come up had it not been for thee;" and another, "I should have been working had it not been for thee;" "I had no cause to come up," said another; and so one charged the others for not being at work.

Son: Did they wish to show any more faults in your mode of ventilation?—Father: Yes; they said I had caused the roof in the tram-roads to fall by changing the mode, and the waggoners said I had made the roads too cold, and they would be 'starven' (starved).

Son: How is it, father, that they would be 'starven,' as they called it?—Father: Because before the change they had to work in warm, impure air, but after in cold, pure air. Yet those miners were very good workmen. They were under my charge a long time, and, I believe, sorry afterwards for the opposition

they had given, as they knew well it was much better for their safety. Many left when the pit was finished, and engaged at a new colliery in the neighbourhood, where much explosive gas generated, and as they had seen the great change for the better in the mode of ventilation I had adopted, I was often requested by them to engage with their new master, as they had great fears of an explosion, which they said would, no doubt, cause great loss, but would be prevented by adopting the improved mode of separate distinct currents of air.

Son: You did not engage, I think, with their master?—Father: No. I had a note from him, with a request to see him, and he assured me if I wanted a situation he would engage me; but as I had a situation, and had no wish to change, and as my employer was in the same mind, I remained where I was for six years longer; I then engaged at the said new colliery.

Son: Then you did engage after a few years?—Father: Yes.

Son: Was the colliery extensive, and one that discharged much explosive gas?—Father: You may judge a little of the quantity of gas discharged, when I inform you of the extent of the place; also there is a letter which appeared in the *Mining Journal*, April 15th; here it is:—

AN IMPROVEMENT IN COLLIERY VENTILATION.

GIVE HONOUR WHERE HONOUR IS DUE.

Sir,—As the subject of colliery ventilation is one of vast importance, the management of our mines ought to be in the hands of sober, careful, and intelligent men. It is some time since the inspector of this district found it necessary to stop one part of a large mine, on account of it giving off a large quantity of explosive gas, and the workmen's lamps were, therefore, unsafe to work with. The ventilation was miserable in the extreme, as it was conducted on a wrong principle—throwing the

body of gas on to the men instead of taking it from them. This, then, was the real danger. Some few months ago, Mr. W. Hopton, who wrote the "Conversation on Mines between Father and Son," was engaged to conduct the underground workings. Mr. Hopton very soon gave instructions for some alteration in the ventilation. Having improved the main return air-way, he next proceeded to divide the current into so many separate divisions, thus giving each level or brow a current of pure air to itself, which had the natural effect of clearing the places of gas, and keeping it from the men; and instead of the lamps being in danger, the men can now with perfect safety work with naked lights.*

Mr. Hopton, after years of anxious exertion, has won for himself in this district a name of honour, trust, and deep respect from all classes of society, by making the mines safe where our miners have to earn their bread. Now, sir, if the Government should call for Inspectors, I think Mr. William Hopton ought to be nominated for this district, believing in such a position he would not fail to take his place among the intelligent and honourable practical mining engineers of this country. His manly and careful exertions in making peace and creating good feeling between masters and men, also gives him a place among the nobles of our land; and the wonderful change for the better he has made will, perhaps, save thousands of pounds and many a poor miner's life.

EDWARD A. RYMER,
St. Helens, Lancashire, April 15th. Miners' Agent.

Son: By this a large quantity was discharged, but how large and extensive was the place?—Father: Well, the length of levels direct from pit shafts extended 2,700 yards; also in breadth 11 levels 60 yards apart. Depths of shafts, 440 yards. The winding engine, 300 horse-power, and it would raise six large boxes of coal at once—a weight of six tons.

* In a mine so extensive and generating such large quantities of gas, Mr. Hopton would not allow naked lights to be used, for miners run with lights where they should not.

Son: You must, father, have had a large quantity of gas discharged in a mine so extensive.—Father: And so there was.

Son: I am very glad, father, you have not had any loss of life, and that the men at the old colliery knew that your mode was the best for the preservation of their lives.

PRESENTATION TO MR. HOPTON.

On Saturday, October 29th, 1870, a lecture was given in the Town Hall, St. Helens, by Mr. William Hopton, colliery manager, author of the "Conversation on Mines between a Father and Son." Edward Johnson, Esq., colliery proprietor, presided.

The lecturer spoke on the useful properties of the atmospheric air, its composition, and how mines are affected by its variations in weight; the composition of explosive gas and after-damp, and when mines are in the greatest danger, &c. The lecturer showed gas in the safety-lamp as seen in a mine when it explodes, and also exploded a miniature mine. He gave experiments on oxygen, hydrogen, nitrogen, and carbonic acid gases. He remarked that there always had been, and he feared always would be, explosions under the best managers; yet he believed that if a proper system of ventilation were adopted, and firemen and deputies understood better the laws of nature, the loss of life would not be so often, nor so great when they did take place. Many lives had been lost, he believed, and men often worked in jeopardy in explosive gas, when the danger might at once be removed if they only knew nature's laws better. The lecturer was well received, and the chairman, in his closing remarks, said that all must have been highly gratified. He believed such persons as Mr. Hopton were much needed, and hoped it would not be the last lecture he would give them. At the close of the lecture, Mr. Hopton was presented with a gold watch, albert chain, and pocket compass, and on the watch was engraved the following inscription :—

"*Presented by the miners of the St. Helens Colliery to Mr. Hopton, manager, as a mark of their esteem and appreciation of his services.*" *October* 29*th*, 1870.

The watch was a gold centre seconds lever, by Mr. James F. Hilton St. Helens, jewelled in ten holes, with compensating balance.

Mr. Leivesley, a fireman at the firm, and one on the committee of seventeen persons chosen by the members of the St. Helens Collieries, numbering over five hundred hands, and in the employ of Pilkington Brothers, in presenting the testimonial said:—"I rise with feelings of pleasure to present this gold watch and albert, willingly subscribed by them as a mark of respect and the high esteem you are held in by them for the valuable services executed by you for their safety. Wishing prosperity may always attend and crown your labours in the management of other collieries, as it has in that of the St. Helens collieries, the men believe that honour ought to be given where honour is due. They remember the great danger they had in working very much in explosive gas when first you took charge, and the great change for the better effected by your arduous study and labour for the safety of life and property, and for which this gold watch is presented as a mark of the high esteem and approval of your services."

Mr. Hopton said—"Mr. Chairman and friends—This useful and splendid gift is an honour I never expected—the gratitude for which is too great for my tongue to express the emotions of my heart. This splendid gift will be valued by me as long as memory holds its seat, and by my children's children when my bones are mouldering in the grave. I have not done more than my duty, and what every person should in similar situations—endeavour always to protect life and property. I have now left the collieries, having given a proper written notice to William Pilkington, Esq., who engaged me, for reasons best known to myself. I have left on friendly terms, as you may tell, having continued, on their account, one fortnight after the expiration of my notice. The St. Helens collieries are very extensive, discharging much explosive gas, the workings of which were not, you know, very healthy when I came to them; but in June, 1869, a great change in the ventilation of the mine took place. Twenty-two persons it required separated in the workings one-and-a-half miles from each other—every one having his duty to do in the same second of time; and, after timing all the watches I said, 'Go, men, to your stations; keep awake; let each one do his

duty, not before or after, but at the same second of time; and, if so, be assured success will crown our labours.' I know many prophesied that in its accomplishment we should all be blown to pieces; but having studied well my plans, I knew that success depended only on every person doing his duty at the proper moment, and when it arrived no tongue can express the anguish of my heart when opening a door, with my watch in hand, I exclaimed to myself, 'Are all at their posts doing their duty?' And when only half opened I felt the reversion of the current, and with that reversion a tremendous wind which blew my light out and the cap off my head, and I again shouted at the top of my voice, and my heart went also with it, 'Yes, yes, everyone has been in his place and doing his duty.' Yet, I must tell you the dangers are not all past; now and again sudden outlets of gas take place which will require great caution and care; but be assured nothing on the part of the employers will be wanting that they can do, if they know, for your safety. I advise you to work honestly; do labour equivalent for your wages; for the success of your employers is closely connected with your prosperity. I thank you again and again for this splendid gift."

A vote of thanks was passed to the chairman and lecturer, when the meeting terminated.

Mr. Hopton was four years at the St. Helens collieries; after which he "re-engaged" as manager at the Sutton Heath collieries, for James Radley, Esq., with whom he had served nine years previous to his engagement at the St. Helens collieries.

The Friction of Air in Mines, and several ways shown by which it is produced.

Son: I shall be glad, now, to have a little conversation in reference to the friction of air in mines.—Father: I shall be glad to give you all the information possible in reference to the "friction" of the air, as it is a very interesting subject.

Son: Friction is caused, I understand, father, by rubbing or dragging one body against another?—Father: Anything dragged along or rubbed against another thing produces friction. To illustrate the case more clearly, I will show you that friction may be produced in several ways. Firstly, a ball will not roll the same distance on gravel as if rolled on ice, because on the ice there are fewer obstacles than on the gravel; therefore, it is the rubbing or friction of the ball against the gravel which retards its progress. Secondly, a break pressed against a fly-wheel when in motion produces friction; and more weight or pressure added to the break against the flywheel, will increase the friction until the flywheel is at a standstill. Thirdly, in proportion to the surface rubbed, so is friction produced—that is, if only one square yard of surface is rubbed, the friction will only be one-fourth of that caused by rubbing four square yards of surface. Fourthly, friction is diminished or increased in proportion to the velocity it travels at; by doubling the velocity you increase the friction four-fold; that is to say, if a vessel at sea can only be propelled 20 miles in a certain space of time by, say an engine of 100 horse-power, it will require an engine of 400 horse-power to propel it the same distance in half the time, because friction increases in proportion to the square of the velocity.

Son: What do you wish me to understand, father, by the rolling of the ball on the rough gravel, the pressure of the break on the flywheel, the difference of friction produced by the large and less space of surface rubbed, and the increased power required to propel a vessel to travel at a double velocity? that is, am I to understand anything in reference to the friction of the air in mines, by the same?—Father: By the above, I hope

to show you how friction of the air in mines is produced in four different ways. In passing air through and around the workings of a mine, it presses against the roof, floor, and sides, and, by such pressing and force, friction is produced; and so great is the friction of the air in some air-gates that it may be heard to make a noise or sound as it rushes through them. Therefore, if air-gates be not smooth, even, level, and free from obstructions, but are rough, rugged, unequal, and not regular, the air-passages will produce more friction than if smooth.

Son: I see by this, that if an air-passage be smooth, the same air will rush through it with less friction than if rough, just as a ball would roll on the ice with less friction than on gravel.—Father: Yes, and the more the air is compressed through the workings, the more is the friction produced by the compression; and, if air is propelled around six groups of miners, the friction, drag, or the rubbing of that air against the roof, floor, and sides, will be much greater than the friction produced by conducting the said air around one division of miners; and, as the flywheel comes to a standstill by the great friction or weight of the break upon it, so also will air, if too compressed, from being compelled to drag, or rub through a large space of surface, come to a standstill.

Son: I also see, father, that as there is more friction produced in rubbing four square yards of surface than one, so is there more friction produced by conducting air around six divisions of miners than one; and, as you say, the flywheel comes to a stand by the great friction of the break, so will air also in mines come to a stand, if the distance which causes the pressure be too great for it to travel. But, father, is there not another way by which friction of the air in mines may be seen—that is, by its velocity?

—Father: If you cause air to travel at a great velocity, you very much increase the friction. You have seen, no doubt, ships at sea, or vessels in a canal, propelled by the force or power of the wind, at a great velocity, because the force of the wind against the vessels, which propelled them forward, was very great. Therefore, to propel a vessel forward at the same velocity, if there were no force of wind against it, would require an engine of great power to do it. Well, if the force of the wind which propelled the vessels forward at such velocity were reduced three-fourths, the vessels would only travel at one-half the velocity. So, in like manner, is ventilation produced in mines. If 20,000 feet of air can only be produced for the workings of a mine per minute, by the power or temperature of a furnace, it will require the furnace to be increased in power four fold, to produce double the quantity of air, because, as before stated, the friction of the air increases in the same ratio as the force, and the force increases as the square of the velocity. As that is the case, it requires four times the temperature to produce double the quantity of air, and sixteen times the temperature to produce four times the quantity of air, because the force of the air against the roof, floor, and sides, which produces the friction, is very much increased by the velocity.

Son: Suppose, father, two divisions to be of unequal lengths, one 800 yards from the down-cast to the up-cast, the other only 400 yards, and the area of the air passages each to be alike, nine feet. I wish to know why air rushes with greater velocity on the shorter route than on the longer one?—Father: Because there is less friction in one than in the other; or, in other words, the balance of friction in the two is not equal; therefore, as an increased velocity produces friction, and there is less friction in

the shorter route, the air rushes in to equal the balance of friction between the longer and shorter route.

Son: I shall be glad to know, father, what quantity of air would rush into each gateway to balance the friction in the two? —Father: Well, if you had, say, 12,428 cubic feet of air for the two divisions, to produce the same friction in the shorter division, as that in the longer one, it would require nearly 7,280 cubic feet of air to rush in, and the longer would require only 5,148 cubic feet; thus, the longer division would lose 1,066 feet, and the other would gain the same quantity of air over and above its own quantity. By this it will be seen that there is a great loss of air from the workings when air is propelled around a great number of works, as the furnace would have produced the same quantity of air for the longer route as the shorter one, had it not been for the extra friction. One thing I wish to impress on your mind—that air will always balance the friction in each and all divisions. The distance the air has to travel, and the quantity of air in each division, may not be equal, but air will rush more or less into all parts until the balance of friction in all be equal.

Son: You say 5,148 cubic feet of air will rush into the 800 yards division, and 7,280 cubic feet into the 400 yards division, and that amount of air in each equals the balance of friction in the two. How can I prove that to be correct?—Father: You multiply 1·4142136 by 5,148.

Son: Why multiply by that number?—Father: Because, if you double the velocity of the air in any division, the friction becomes four times greater than what it was before. Therefore, as the friction in the 400 yards division may be said to be one, but two in the 800 yards division—(as its distance is double that

of the other)—all that is required is to multiply 1·4142136 by the quantity of air which rushes into the 800 yards division; and it will give the number of cubic feet of air which will have to rush into the shorter division to equal the balance of friction (to two) like that in the longer division.

Son: Suppose you had five divisions, and a regulator in each division—the air to travel in the first division 200 yards, in the second division 400 yards, in the third 600 yards, in the fourth 800 yards, and in the fifth 1,000 yards; the area of each air-gate being alike; and 10,000 cubic feet of air are to pass per minute through each regulator; can you tell me what open space each regulator would have to be, to allow that amount of air to pass through; the first regulator to be—say 9 feet area? —Father: You may find the open space of each and all the regulators in the following manner. The first regulator is 9 feet area. To find the open space in the second regulator, multiply 1·4142136 by 9; for the third regulator, multiply 1·7320508 by 9; for the fourth regulator, multiply 2·0000000 by 9; for the fifth regulator, multiply 2·2360680 by 9. By so doing, and striking off the decimals on the right hand of the result, it will give you what the open space in each regulator should be. The area of each regulator being larger, one than the other, it will *equal* the friction in each, and allow 10,000 cubic feet to pass. What I have said could never be practically executed in mines, because all and everyone of the air-ways would have to be throughout alike, the same area, alike smooth, even, level, and free from obstructions.

The great friction of the Air produced by one mode of Ventilation, and how the friction may be reduced by another.

Son: I see, father, by conducting air around a long route of workings, such workings will lose much air; also, to form one large current of air from many divisions, and propel the whole through one air-gate of the same area, the friction of that air must be very great?—Father: To show the increased friction by ventilating a great number of works with a large current of air, I will suppose 38,016 cubic feet of air to ventilate the workings of a mine, in which there are, say six separate groups of miners to ventilate, and the area of each gateway is nine feet. To split the whole wind into parts, and ventilate each group of miners separately, each would have, per minute, 6,336 cubic feet of air. This being the case, the air would rush into each gateway, and through the workings, at the rate of eight miles per hour, and its force on one square foot would be a little more than five ounces. Well, but if all the six divisions formed one large wind of 38,016 cubic feet, and the whole quantity had to pass, per minute, through the nine feet area around all the six divisions, the said current would have to travel at the rate of 48 miles per hour, and the force of the current on one square foot would be 11¼lbs.

Son: There is a very great difference, father, between the one and the other, the force of separate currents, in one case only 5 oz., and the other 11¼lbs. Yet there is the same quantity of air produced by one mode as by the other. The air rushes with a force 36 times greater than if each part be ventilated separately; therefore what difference is there, father, between the friction of one mode and the friction of the other?—Father: Well, by one mode, you see, the air travels around six parts, but by the other mode only

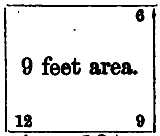
around one. Therefore, suppose one travels 1,000 yards and the other 3,000 yards, the distance would be two-thirds greater by one than by the other. By this the friction in proportion to the distance, will be 72 times greater in one than in the other, and 36 for the great force or velocity added to the 72 will show the friction near 108 times greater in one than in the other. Because the friction in this case is of two kinds—one is in proportion to its force or velocity, the other in proportion to the distance it travels.

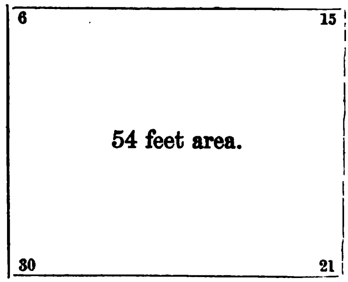
Son : To enlarge the air-gates would prevent this great friction of the air.—Father: Yes, but look at the great expenditure; air-gates would require enlarging from nine feet to fifty-four feet area. This enlarging of air-gates in every place could not be maintained.

Son : But it would, as you say, diminish very much the friction by enlarging the air-gates.—Father: so it would.

Son : To have all the air passing, as you say, through a nine feet area, the friction would be very great; and to pass the same quantum through six air-gates of nine feet each area, would diminish the said friction very much. But, father, would not the friction again be much diminished by enlarging from six air-gates, each nine feet area, to one air-gate of 54 feet area?—Father : Yes, the rubbing surface would be much less in one 54 feet area, than in six each nine feet area; therefore, the friction would again be less in the one 54 feet area, than in the six nine feet.

Son: How much would the rubbing surface be less in one that size than in the others?—Father: In the rubbing surface of the six nine feet there would be 72 feet; in the other, 30 feet only. See—





6 times 12

72 feet
30

Total 42 Diminished, or Less.

Son: I see, father, the rubbing surface is diminished to less than one half.—Father: So it is; therefore you see, it is well, if possible, to enlarge much the air-gates to diminish the friction.

Son: I think the main returns and intakes, father, should be made large.—Father: Yes; but air-gates in the interior of the workings cannot always be kept large, as it would be very expensive to do so.

Son: I see, father, the expenditure would be very great, and the expenditure in furnace power to overcome that amount of friction would also be very great, because the furnace, I see, in proportion to its power, overcomes a certain amount of friction. —Father: Yes. If the friction of the air be very great, the furnace will overcome it, but produce a less quantum of air; but if the friction be not very great—that is, if the air-gates be large enough for the air to travel, the furnace will produce a larger quantum of air for the said amount of friction; therefore, if the friction be great, there is less air produced; for the furnace, as before stated, in proportion to its power, always overcomes the said amount of friction.

Son: Is not the furnace fixed, father, near the up-cast shaft, and constructed to hold a large quantity of fire?—Father: Yes.

But they are not all constructed alike, nor of one size; some are larger, others less.

Son: If large fires are in mines, will not the heat from them ignite the coal, and cause great damage to the underground workings?—Father: I have known coal in mines ignited by the heat of the furnace-fire, and pits closed up for months.

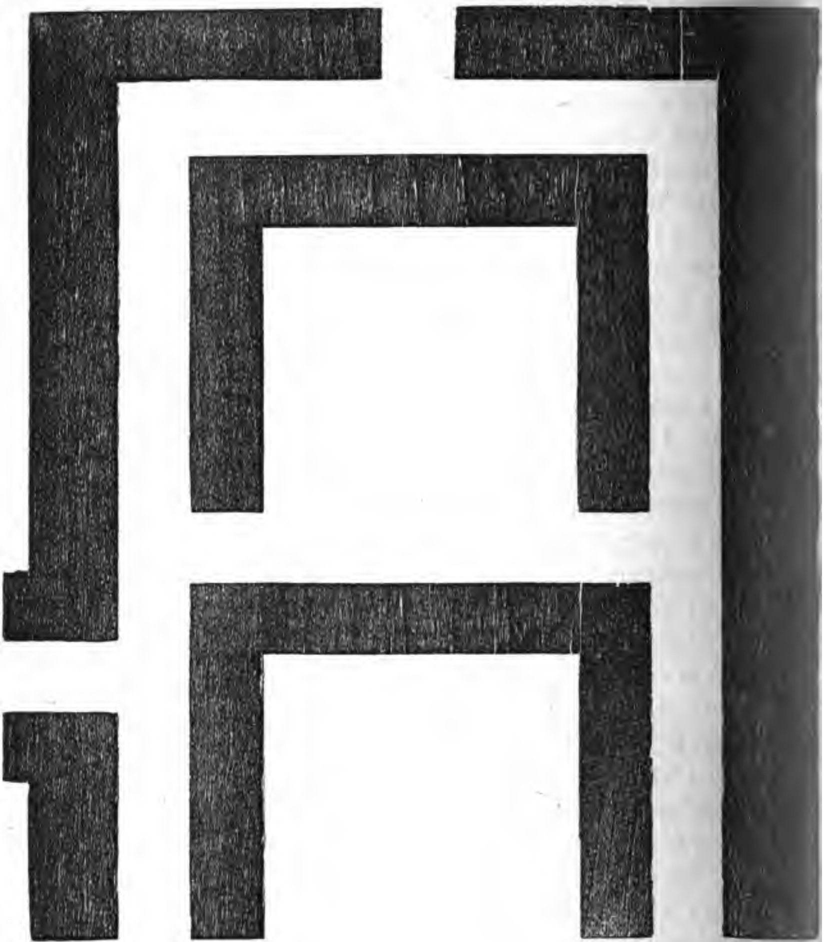
Son: It is possible, is it not, father, to construct a furnace by which the coal cannot be ignited?—Father: A furnace may be constructed to prevent coal igniting. I have a furnace plan of one so constructed. It was given me by the author of it, Mr. John Smith, a very intelligent, well informed person, and overman for years at several large collieries in the north of England, now a certified manager.

Son: I should have great pleasure, father, in seeing Mr. Smith's construction of the furnace.—Father: You may see it with pleasure; this is the ground floor of it. After sufficient space is made in a proper part of the mine near to the up-cast shaft, walls are built, as on the plan. (*See page* 110.)

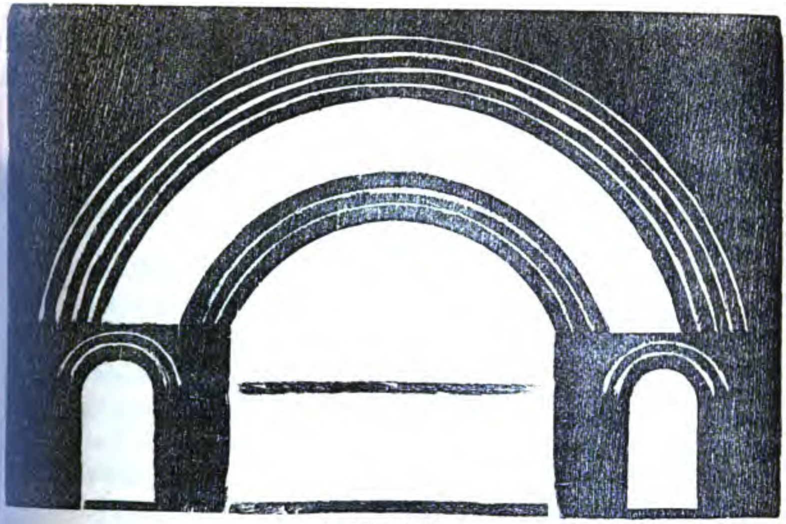
Son: What are the dimensions?—Father: You can make it of what dimensions you think proper. The scale given by Mr. Smith is one-eighth and a sixteenth of an inch, or $\frac{3}{16}$ of an inch to the foot. Mr. Smith gives the plan, but the furnace may vary in size, according to circumstances.

Son: The furnace walls, then, are built sufficiently high for the fire-bars?—Father: Yes; and from thence forward for the walling of the brick arch, over which the said arches span the fire. See also the front view on page 111.

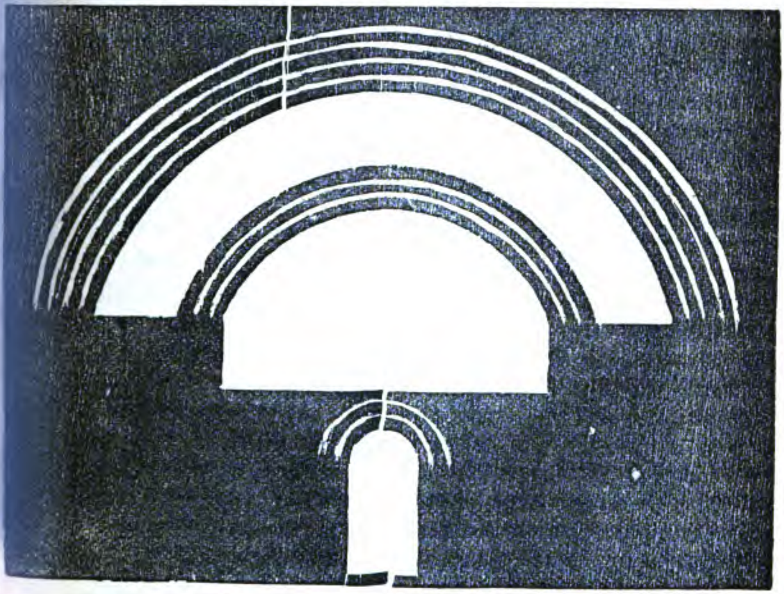
Son: This is the front view, then, father, of Mr. Smith's improved ventilating furnace?—Father: So it is. You see there are two brick arches over the fire, by which air can pass. Also,



FRONT VIEW.



BACK VIEW.



two air-gates, one on each side of the fire, through which the air cools down the temperature of the fire, between one wall of brick work, and the other next the coal.

Son: You say this is the front view. Is the back similar to it?—Father: It is similar to it, but not exactly so. I will show you the back view; see, here it is. (*See page* 111.)

Son: This is, then, a representation of the back part, the black face of the plan being the brick work. The arches, I see, extend across and over the fire, from the front to the back part. I see very well now, father, how a ventilating furnace is constructed. I think this one is very good, and that it is next to an impossibility for coal to ignite by the heat from such a furnace.—Father: I have shown you the ground plan, the front view, and the back view. I think it will not be out of place to give you, now, a little of Mr. Smith's views on furnace ventilation, &c. I will, says Mr. Smith, show that ventilation is of no recent date: yet man knows nothing, or very little, of ventilation. Coal mining, and its mode of ventilation, was to man unknown, till the effects of impure air were felt, or rather seen, by the candle-light, the light being extinguished for the want of pure air, and the approach of carbonic acid gas. Such was the state of things that men were not able to work, as the candle could not burn for the want of pure air. Then at this state of things the pit was relieved by hanging a fire-lamp at night in the shaft, to clear the workings of carbonic acid gas by next morning. This continued for some time, but soon failed to produce the desired effect, after which the fire-lamp was fixed at the bottom of the shaft. It answered a little better for a short time; again it was tried with a larger fire or furnace, laid upon flat grates or bars. This answered much better, yet it also had its faults, and I can name

several pits burnt down by this construction of the furnace. The last improvement is that of making a dumb drift from the furnace to the pit shaft, in the stone roof above the coal, beginning from 50 to 80 yards back from the pit, its rise being, say, from 9 to 12 inches per yard, so that the mouth of the drift will be many fathoms up the shaft. Such dumb drifts were an improvement, but generally they are not attended to, if not altogether given up. Therefore, to eradicate the evils which have taken place, I have constructed an improved furnace, and hope others will try to make more improvements.

Son: Did you not, father, show, on the Lund-hill plan of separate winds, a dumb drift?—Father: So I did, because I knew it would be an improvement; I was also informed a dumb drift was made at Lund-hill, after the publication of my plan. This improved furnace, says Mr. Smith, will be ventilated with fresh pure air, which I have proved to be a benefit to the furnace, by making it burn and blaze more. Yet, some hold it can make no difference, but they know no better. I ask, can a man, or animal, or fire, do as well with foul air impregnated with impurities, as with pure air? Is it not proved that carbonic acid gas will destroy man, animal, and fire? therefore it is pure air, mixed with its proper quantity of oxygen, that is required; without it neither man, animal, nor fire can live. Others hold that only a small portion of air can pass over a furnace. This has been the orthodox idea of scientific viewers, who have had little practical experience. But I am able to show, and prove, that almost an unlimited quantity of air has, and can, pass over the furnace. An experiment was tried at North Seaton Colliery, March 19th, 1863, by Mr. G. Scott, viewer, myself as overman, and Mr. Andrew Newton, furnace-man. In opening the separating

doors to the furnace, to let in fresh pure air, it was found the air rushed in over the furnace with wonderful rapidity, yet this great gush of air did not diminish, but increase, the air passing around the workings in the interior of the mine. The characteristic of this improved furnace, is a double arch, to allow columns of gas to pass through without coming in contact with the flame of the furnace, which so repeatedly cost both life and property. Flues are provided also to keep the furnace clean, and prevent it igniting the coal on each side, from which a proper quantity of pure air can be supplied.

Son: I think, father, Mr. Smith's plan of the furnace is very good; I also think with him, that furnaces should be supplied with fresh pure air.—Father: I believe many lives have been lost by gas igniting at the furnace; some suppose the explosion at Lund-hill took place at the furnace, and at the time my father, or your grandfather, was lost, the opinion of many was, that the gas ignited at the furnace.

Son: I am very glad, father, for this information on the friction of the air in mines, and also of the furnace. I wish to have a little information now in reference to the working out of coal in mines, and why so many ways and plans are adopted.—Father: It is my wish to give you all the information possible; and when we next meet I shall have great pleasure in doing so.

Several modes or ways by which Coal is worked out in Mines, and why so many methods are adopted.

Son: You have seen and adopted, no doubt, many ways of working out coal since you were first engaged in coal mining?—Father: Yes, I have adopted many ways, because I know that the same mode of working out coal will not answer with safety and economy in all mines. One plan of working it out may answer well at one colliery, but not in every one.

Son: Why will not the mode which answers well at one colliery not answer in all mines?—Father: Because the nature of the roof, floor, and coal is not alike; neither is the pressure nor the production of gas in the coal, floor, and roof alike in all.

Son: Does the roof, floor, coal, and pressure, vary much, then, in mines?—Father: Yes, at one colliery the floor is soft, but hard at another; in other mines the roof and floor are both soft, in others both hard; the floor heaves in some mines, but in others not so; in some mines coal is hard, but soft in others; the pressure of the roof upon the workings is very great at one colliery, but not so great at another; gas in the roof, &c., prevents, at some collieries, tram-gates being cut through the whole coal to the extremity, as there would be no end of the falling in of the roads by cutting them in the whole coal; yet in other mines, if the roads are not so cut, they would fall very much; in some mines the seam of coal is very thick, but in others very thin; also, the coal lays flat in some mines, but dips, or rises very much in others; there are many throws, faults, troubles, veins, seams, bad and soft coal in some collieries, but, in others, the coal is all good, and nothing to impede plans in operation.

Single tram-gates may be cut through the whole coal at some collieries to a great extent beyond the current of air, by which managers in charge of the same will be able to adopt plans in contemplation, while the discharge of gas in other mines will not allow tram-roads or narrow work to advance two feet beyond the current. The disadvantages to contend with in some mines are so numerous that a good profitable mode of working out the coal cannot be adopted.

Son: I see now, father, why so many plans are adopted. As you say, one is because the floor is hard, another because it is soft; one is adopted for this thing, and another for that. Therefore I think no person should condemn any mode of working out coal unless he knows well the nature of the roof, floor, and coal, and all the disadvantages connected therewith; as the plan he condemns may be worked with economy and safety where it is adopted, and also may be the best that can be used for that seam of coal.—Father: Yet many plans adopted are not useful, as they have been adopted by managers not having a proper knowledge of the nature of things. Therefore every underlooker or manager of mines should have a good knowledge of the nature of the roof, floor, coal, &c.; and also a good foresight of his contemplated plans. He should have such a foresight as to see in his mind's eye the plan at work, before he adopts it. If not, he cannot see his way clear before him as he should do, but, like a person bewildered in a thick mist, adopts unmatured plans, which will end in injury to the men under him, and loss to his employer. His object should always be to adopt the best plan to suit the seam of coal to be worked out and not to change because he may see a good plan of working coal drawn well on paper; or may have heard of a good plan adopted at some other colliery.

Son: I presume, father, some mines require much care and attention to produce a good profit for the employer, and ensure safety to the men?—Father: Yes; some mines cannot be worked with a good profit if all the plans in use are adopted. So changeable is the roof, &c., in mines, that in some of them no plan appears to answer well. I have known—and had to manage—mines, where, in one pit, the plan which would answer well on the north part, would not answer on the south.

Son: By what you say, I clearly see one colliery would be much better to manage than another. Therefore, no doubt, father, some managers have got a good name, not because their knowledge of mines was great, but because they have got a good colliery to manage; while others with a good knowledge of mining, have been discharged and disgraced, because neither they nor anyone else were able to make the colliery under their charge pay a good profit to their employer. As you have clearly shown the cause why so many ways of working out coal are adopted, I shall be glad to know, father, how or by what way coal is worked out?—Father: One mode is pillar, stoop, or room-working; long wall working another; bank or wide working another: and others work coal out in drifts, yet each and all the modes vary in the way of working.

Son: What am I to understand, father, by pillar, stoop, or room-working; that is, in what way is coal worked under those methods?—Father: Pillar-working is adopted in several mining districts, but universally so in the north of England. To get coal out in pillars, narrow work is cut in the whole coal into square blocks, the narrow work being cut endways and crossways of the coal, by which square blocks of coal are formed. This mode will find room or places for a great number of miners

—some in cutting narrow places, others in working out pillars, the pillars always being worked out next to the old gob or goaf; that is, one pillar worked out next to the last one worked out.

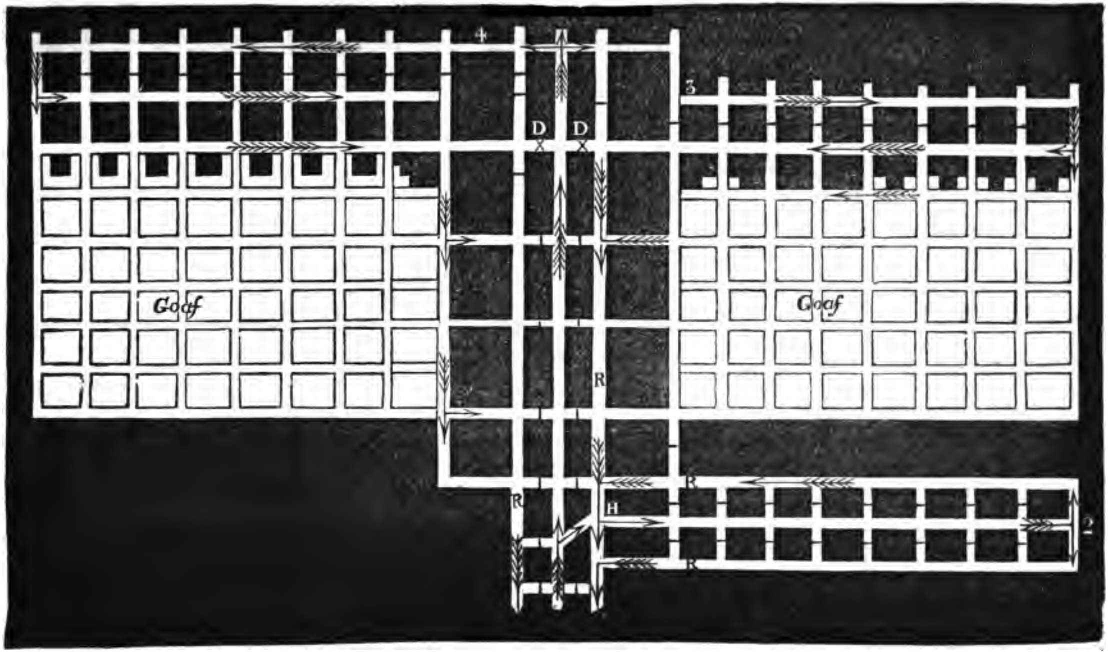
Son: Are the blocks or pillars square, and all of the same size in every mine?—Father?—No; in some mines they are square, but in others they are not; neither are all the pillars of one size; they are cut large or small, to suit the seam of coal, roof, or floor where such pillar-working is adopted. If you inspect plan No. 7 it will give you a better knowledge how or by what way pillar working is adopted.

Son: I see by the plan that narrow places are cut in the whole coal in two directions; this way of working will, I see, make square blocks of coal to be worked out. This, father, is the plan of coal working universally adopted in the north of England?—Father: Yes; it is the mode they adopt, and plan No. 3, page 74, also shows pillar working.

Son: Yet the mode of ventilation on plan 3 is not the same as the mode shown on this plan?—Father: No, this plan shows split winds, and not like plan No. 3, a mixture of winds. If you inspect this plan you will find four divisions for the number of works.—See Nos. 2, 3, and 4, where the air is divided. The letter H shows the overthrow. The letters R R, regulators, and D D show the position of the doors.

Son: I am glad, father, for the knowledge I have received from you. I think I can see, in my "mind's eye," how pillar working is adopted; but how is coal got out by long-wall working?—Father: In long-wall there are many ways adopted. One is to work a great number of tram-roads, or narrow places, through the whole coal to the extremity of the block of coal to be worked out; after which, say 100 or 200 yards, or

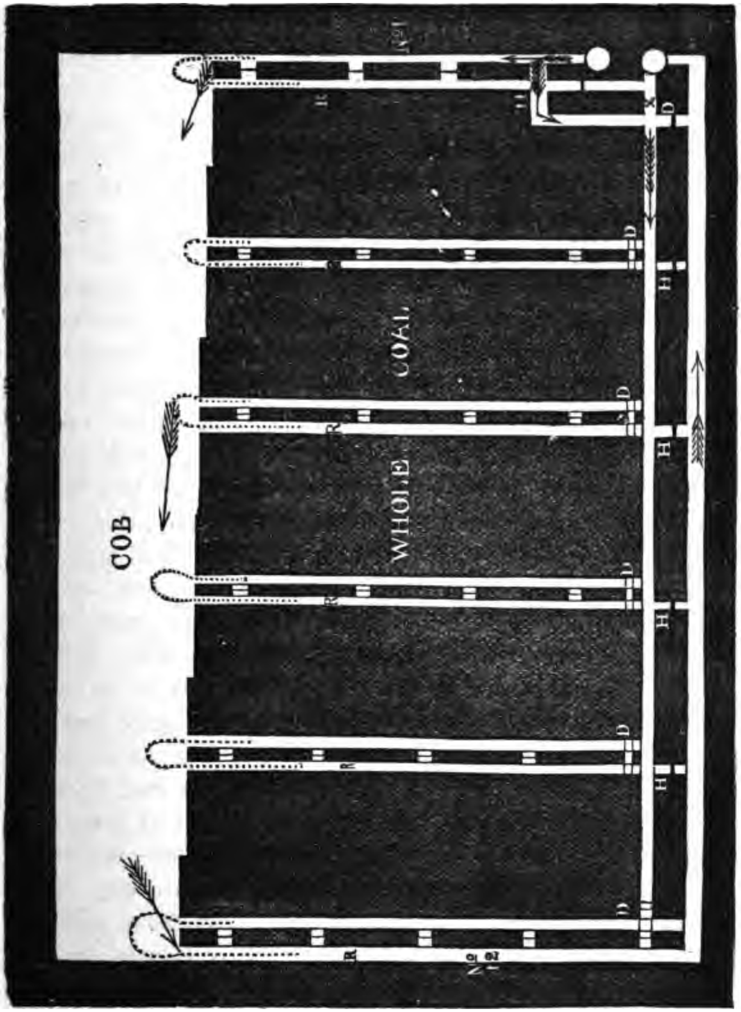
PLAN No. 7.



more, is brought back from the extremity, and the gob or goaf left behind. Plan No. 8 is a representation of the said mode of working. You see the whole coal, and tram-gates cut through the said coal, and also the gob or goaf where coal is got out, left behind. The mode of ventilating the said workings is to conduct the air in at No. 1 gateway, from there across the whole breadth of all the working faces to No. 12 gateway, and from there in one current to the up-cast. As before stated, a large quantity of gases are always collected by this mode. Yet, each part may be ventilated separately if overthrows are only fixed at the letters H H, and each separate division of air regulated at the letters R R. In this case all the doors would have to be removed, except the one near the up-cast. Yet, this is not the only way of long-wall working, as others commence at the beginning to work out the large breadth of, say 100 or 200 yards of coal, the whole breadth being worked out to the extremity, the tram-roads being made through the gob, goaf, or sink to the working face, as the said face extends into the extremity of the mine.

Son: How, father, are tram-roads cut or made through the old gobs or goafs to the working face? Is there not great danger in so working coal out? And, also, are tram-roads made through the gobs a great distance to the working face?—Father: To make tram-roads through the gob, a four feet stone wall, or thereabouts, is built upon each side of the road, as the coal or working face extends forwards. These stone walls prevent the roof falling in, until the great pressure causes the roof and floor to nearly meet, by which the floor is either cut up, or the roof cut down in the roads to make them (as the roof and floor meet) of the proper area. When finished, they look like stone drifts or tunnels, which will stand good a long time. As to danger, it

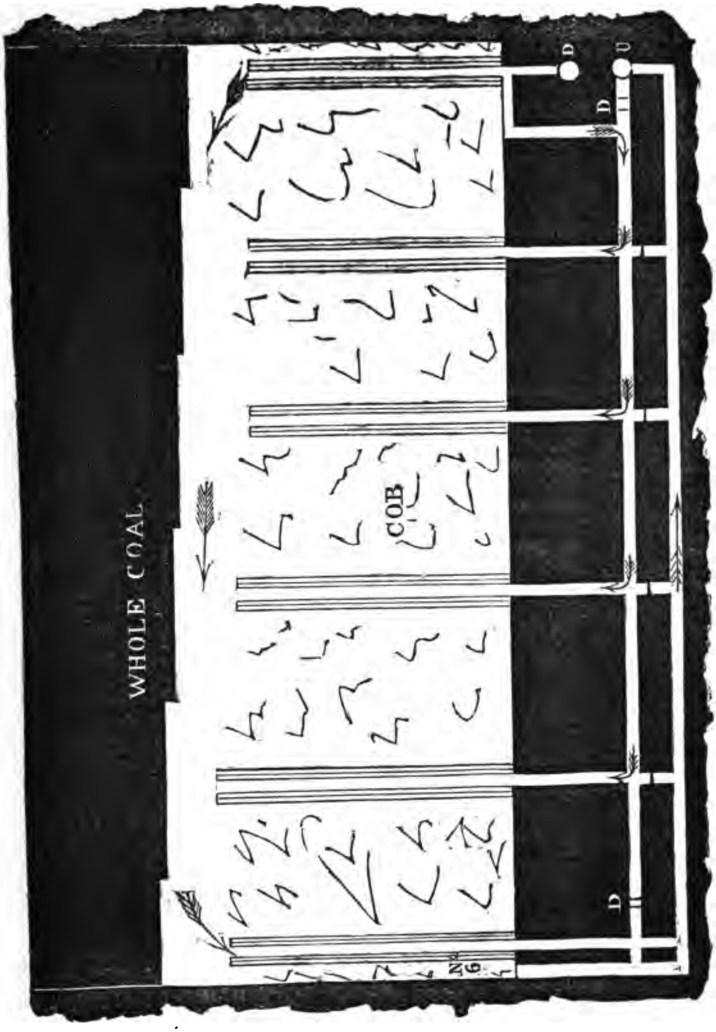
PLAN No. 8.



is not so great as by many other modes of coal working; and the said roads may be and are cut a great distance through the old gobs, goafs, or sink.

Son: You say 100 or 200 yards, or more, of coal is worked out all in one breadth. Can this large breadth of coal be worked out in every mine where the said mode of coal working is adopted—that is, can you see all the men at work from one end of this large breadth of the face to the other?—Father: No, not in all, you cannot. The breadth of the face of coal worked out is in proportion to the strength of the roof. If you inspect plan No. 9, it will give you a knowledge of this mode of working. The whole coal or the face of the workings has to be got through the old gob. The mode of ventilating the workings is to pass the air fresh into every gateway, except at No. 6, at which place the whole of the air meets; after ventilating the said place the air goes onward in one current to the up-cast. This mode of ventilation may be said to be similar to plan No. 2, page 71, by which pure air is mixed with impure air. Yet this mode of ventilation is not good, as the whole of the gases generated in all the workings are collected to No. 6 working place, so that an explosion there would affect every other part of the mine. Therefore, ventilate the same separately, by passing air fresh up one gateway, and return it on the other. As to the mode of working out the coal, when the strength of the roof, &c., will not allow the whole breadth to be worked out at once, the breadth is diminished accordingly; that is, two tram-gates work out their own breadth, advancing first into the extremity, other breadths follow up, one advancing a short space before another by which the pressure upon the working faces is diminished, or equalized in all parts.

PLAN No. 9.

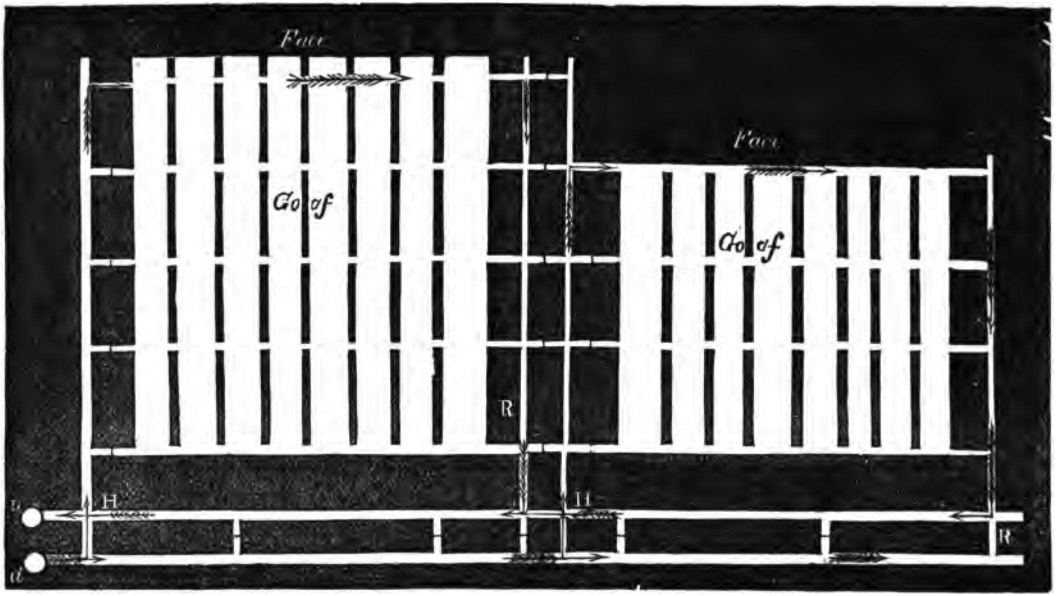


Son: Then I presume, father, when narrow places or tram-roads are worked through the whole coal to the extremity of the coal, the whole breadth of the 100 or 200 yards is not brought back all at once?—Father: No, not always; it is often worked back in lengths, one before the other, as may be seen in plan No. 8.

Son: I am obliged, father, for the information on long-wall working. I now wish to know by what way coal is worked out by bank or wide work?—Father: Wide work or bank work is similar to long-wall or long work, only the tram-roads are not made to the working face through the old gobs, but 60 or 100 yards of coal are worked out in one breadth, the tram-roads being cut in the whole coal on each side of the wide breadth of coal worked out.

Son: Is all this width of 60 or 100 yards got out, that is, is any coal or pillar left to support the roof, as the coal is worked forwards into the extremity?—Father: In many mines the whole of it is worked out: and in some mines a rib of coal, one yard in width, is left between every ten yards, to support the roof—a hole being made through those ribs or posts of coal through which waggoners pass and repass with coals from the working face, and as the bank face advances, new holes are made through the ribs or posts, by which a new road is made next to the working face. You will have a better knowledge of the mode of working by inspecting plan No. 10, which is a representation of this method. Ribs of coal are left, you see, between each working place, and as the face advances, new roads are cut through the ribs of coal across all the working places, and in like manner, new roads are formed as the face advances by being worked out. This mode of coal getting may also be seen in plan No. 4, page 79, as the two plans are similar, except that in one the coal is

PLAN No. 10.

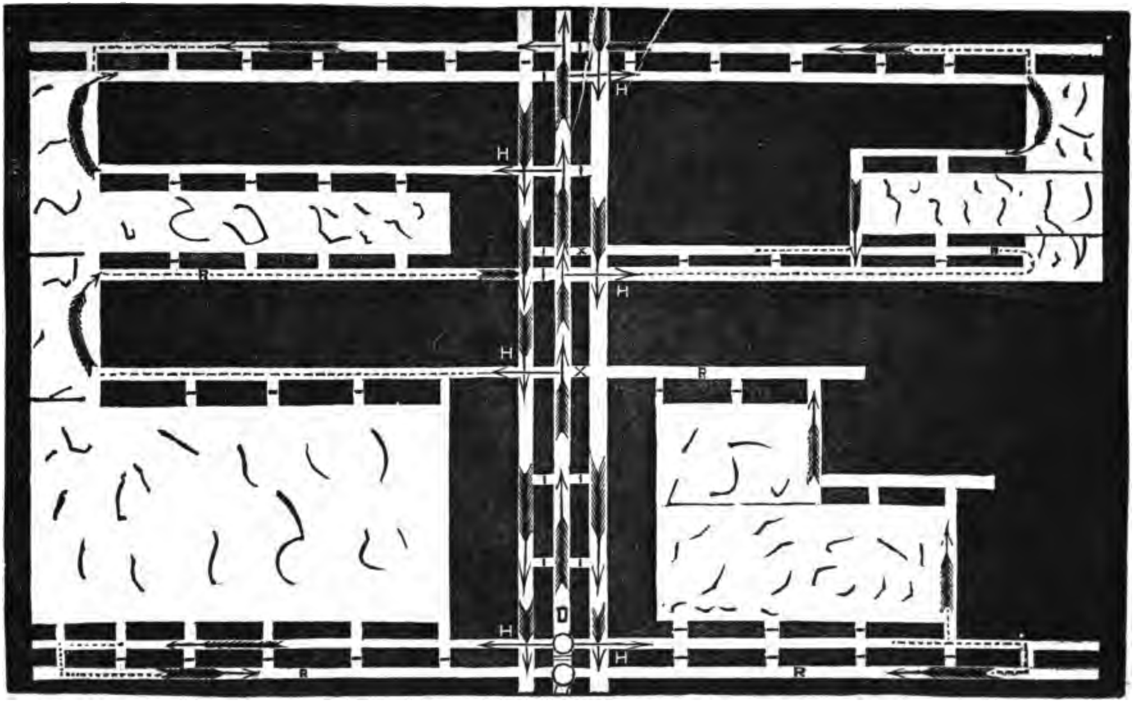


worked out from the commencement of the extremity of the block of coal, and in the other the working is commenced at the extremity, and is continued in the return homeward to the commencement of the working. Also, the mode of ventilation is, on this plan No. 10, to have separate windings for each bank or working place.

Son: You say, father, to work out coal in bank or wide work, 60 yards or more is got out in one breadth, and worked away from the commencement to the extremity of the block of coal; also, for the conveyance of coal from the working faces, tram-gates are made in the whole coal on each side of the large breadth of coal worked out. I wish to know, father, if this is the only way of getting coal out in bank or wide work?—Father: It is not the only way. In some mines the whole 60 yards of breadth is not worked out at once, but one-half only. The other half is followed up a little behind the first one, or if the whole breadth is worked out, another breadth of, say 30 or 40 yards, follows up the first. You will see the mode of coal working in plan No. 11. The whole breadth of coal is not worked out all at once, but one breadth takes the advance, and the other breadth follows after, tram-gates for the conveyance of the coal being cut in the whole coal on each side of the breadth worked out. Also the mode of ventilation is that of split winds.

Son: Is there any other way by which coal is worked out in wide work?—Father: Yes, the following:—A great number of tram-gates are cut on the "end" of the coal to the extremity of the block to be worked out, after which coal is worked away on each tram-gate homeward or backward to the pit eye. Now, as tram-gates are cut in this case on the "endway" of the coal, the coal is worked away in breadths between tram-gate and tram-

PLAN No. 11.



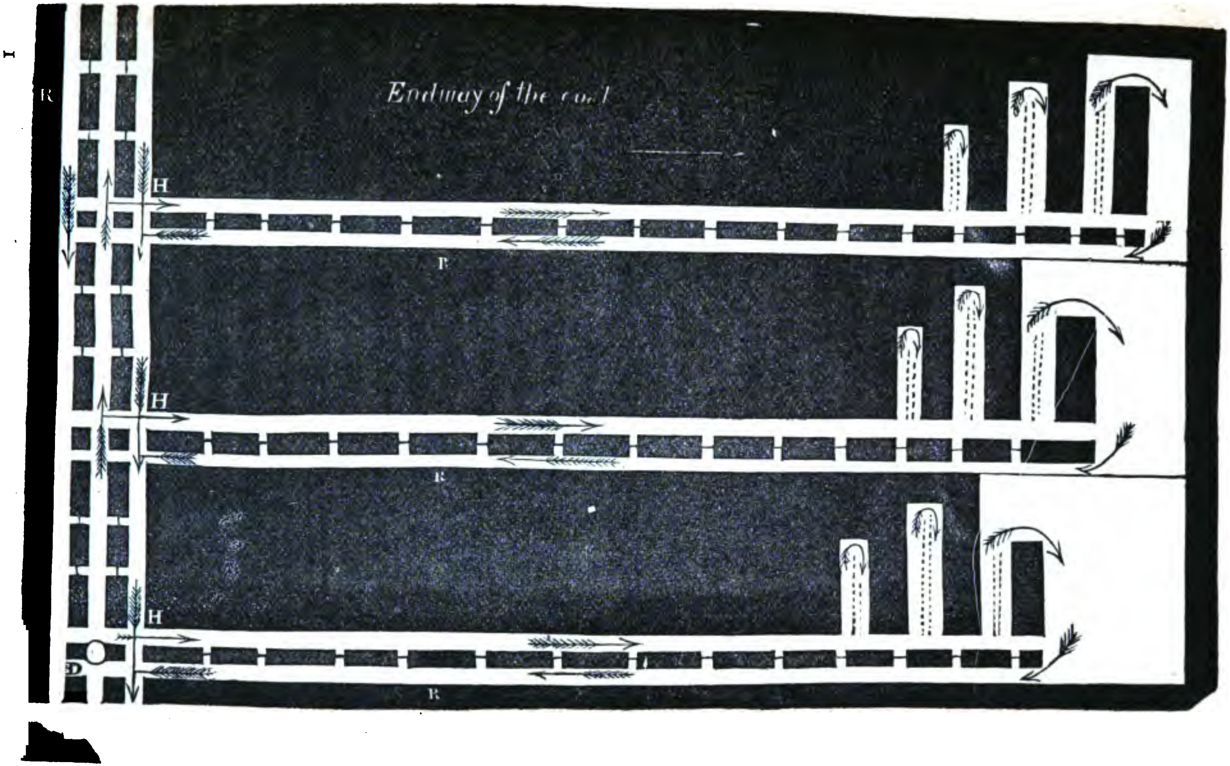
gate,—that is, a wide place from 10 to 20 yards in width is worked out between one tram-gate and another, on the boardway or face of the coal. When finished, another is worked away, next to the last one, and so continued until the whole of the coal is worked away backward from the extremity. You will see a representation of this mode of working out coal in plan No. 2, page 71.

Son: I see by this mode, father, that as tram-gates are cut in the whole coal in plan No. 2 to the extremity, and worked back in wide places, the goaf or gob will be left behind?—Father: Yes. This mode is often called heading or ending work, because narrow places or tram-gates are cut, not on the boardway of the coal, as in plan No. 11, but on the endway of it.

Son: Very good, father; but how is coal worked out in drifts? —Father: The mode of working away coal in drifts is similar to that shown in plan No. 2, it being worked away in headings or endings. Narrow places are cut, as before, on the endway of the coal, after which blocks of coal from six to ten yards in width are worked out between one heading or tram-gate and another, a pillar or post of coal being left between two drifts, and pillars being worked backward (after the drifts are finished) to the tram-gate. For your better information I must again refer you to plan No. 12, as you will by it have a better knowledge of the said mode of working. The mode of ventilating the works is that of separate windings.

Son: What distance may these drifts be worked in from the tram-gates? and what width are the pillars or posts?—Father: The distance of the drifts worked in and the width of the pillars vary much. The width of a pillar varies from six to ten yards or more, and the distance of drifts worked in also varies from ten to forty yards or more.

PLAN N. 12.



Son : Is there any other mode, father, by which coal is worked out?—Father: There are other ways of getting coal, but in many there is no regularity.

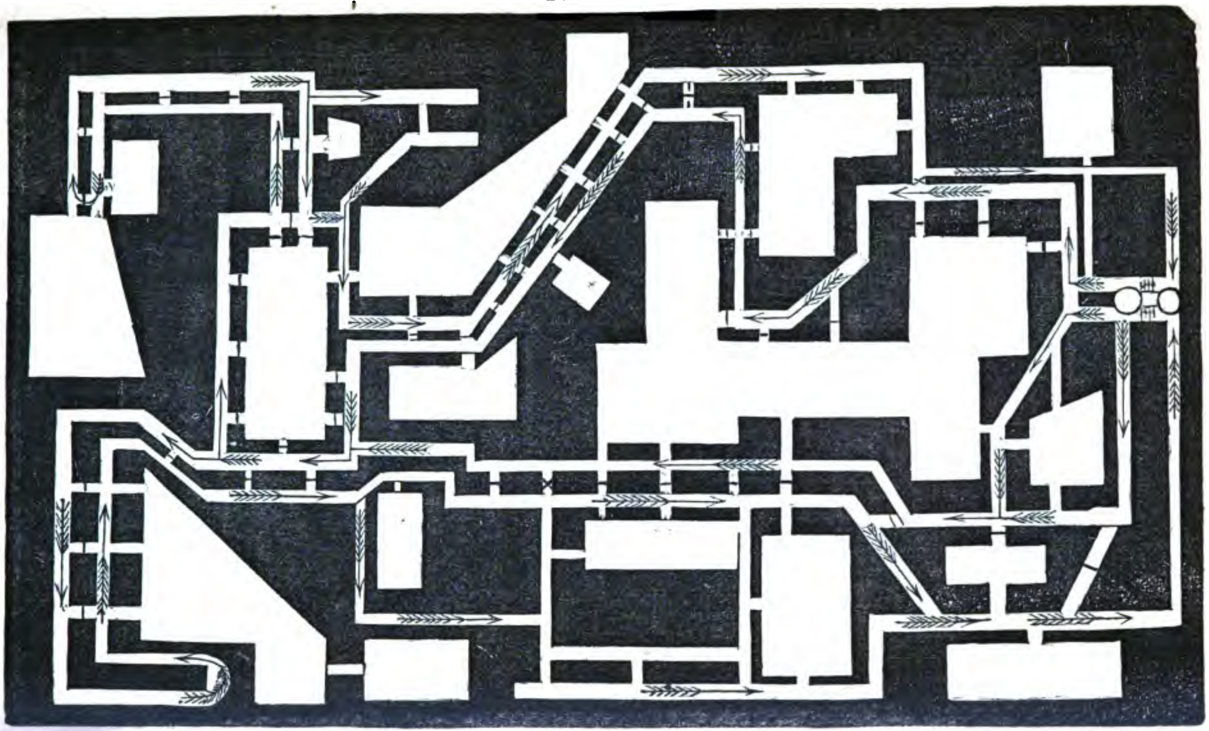
Son: Why is there no regularity in the mode of getting coal out in some mines?—Father: Because it is worked out from any place, anywhere, and in any way. If you wish to see a plan of an irregular working, an inspection of plan No. 13 will give you a little knowledge of one such as I have described.

Son : What object do managers wish to accomplish by so working or getting coal?—Father: They have several objects in view. One is to get a large quantity of coal, and produce a good profit for the employer. Another is to impress on the public and the employer's mind that they excel others in management.

Son: Is it not every manager's duty to get out a large quantity of coal, and, if possible, to excel others in the management of mines, by which the employer may be profited?—Father: Yes; but if coal is not got out in a proper way, the profit produced will only be of short duration, as often large blocks of coal are left between two "goafs" or "gobs"; and, to work such blocks of coal out, there is often loss of life, great expenditure, much loss of coal, and, for the conveyance of the coal, roads of a circuitous route have often to be made, and many dangers met with.

Son: You know, and have seen, then, mines worked in the way you state?—Father: Yes, several; one colliery in particular, which would have been a good colliery for a number of years had it only been properly managed. It cost many thousands of pounds, but the proprietors would have been glad for any person to take it off their hands. It is now abandoned, with a loss to the proprietors of many thousands of pounds.

PLAN No. 13.



Son: Was the manager of the colliery a person who had a good knowledge of mines?—Father: He professes to have, as I know he takes tradesmen's sons as pupils, to qualify them for underground managers.

Son: Is the manager still at the same colliery, or was he discharged?—Father: Discharged—no; he had produced too good a profit in the short time he had been there to be discharged, and it would have been impossible for any person to impress on the minds of the employers anything disrespectful of him; yet he knew better than to remain there when the inside of the pie was got out, and another colliery was offered to him.

Son: Then those who came to manage the colliery after him would not be able to make it pay so well?—Father: No, neither could he, nor any one else ever be able to make the colliery pay a good profit afterwards.

Son: I think if his pupils never have any practical knowledge of mines, but what he can give, it will be very little they will know of mines.—Father: If a person intends to be expert in the management of the underground workings of mines, he must be taught in a mine, and not out of it; or he will have nearly the same knowledge of a mine as a mine would have of him. I have been in mines forty years, and yet I find things in which I can profit constantly occurring.

Son: Are there no good, practical, and talented men to be found in mines to manage the underground workings? and if so, is it not a disgrace to place a tradesman's son in such an office?—Father: There are in mines many practical men, and men of first-class knowledge, well able to take the management of the underground workings, but they are not allowed to do so. A tradesman's son must take that office, and he who has served

all his lifetime in mines must ask one of these pupil-managers how the works are to be conducted, while he (the practical man) knows much better himself. It is not my wish to condemn all, as not fit for managers, who have not had a practical knowledge of mines; there are exceptions.

Son: I think it is time, father, that something was done to place the right man in the right place. You would be thought a strange person to take the command of a ship at sea, and to have a great number of lives and a large amount of property under your charge, without your having a practical knowledge of navigation.—Father: Yes; but a practical man is down, and a great number of people would keep him down. Their object is to get themselves, or some one related to them, into the place which would elevate the practical man; but I hope the day is not far distant when every practical man who has got the abilities in him to manage, will be brought out from the ranks, and the whole form one institute, in which they will receive a knowledge of dialling, of laying the working of a mine on plan, of gases—how they generate, of ventilation, of working out coal in mines, &c., &c., and every one shall pass through an examination, after which he shall be recommended to colliery proprietors in the whole kingdom.*

Son: Should not underground managers have a knowledge of the capabilities of the workmen under their charge, so as to appoint the right man to the right place?—Father: Yes, because some workmen have a better knowledge than others of gases, ventilation, fixing doors, overthrows, stoppings, bars, props, rails, laying and preparing roads, &c.

* The examination for mine managers took place by Act of Parliament in 1873.

Son: They should also have, I think, a good judgment of every person's work, so as to give to every person his right and due, and not to show their management by deducting the workmen's wages, as some, I fear, often do; but if they will show a good profit for their employers, let it be by excelling in management.—Father: You are right; if a person can show his employer no profit but what he can take off a poor man's wages, the sooner he is removed the better; his object should always be to better the employed as well as the employer—to do right to all.

Son: Is not the labour in mines much better to do in one part, and attended with more profit to the miner, than the labour in another part?—Father: Yes; and such being the case, the manager ought to give every miner an equal share of this better work, as far as it is possible, and not give the whole of it to those persons who may have obtained his favour by spending a convivial hour or two with him after the toils of the day or week. Fault-finders or tale-bearers have all the better work.

The best and most competent Persons to manage the Underground Workings of Mines.

Son: Who do you think are most competent, father, to manage the underground workings of mines?—Father: Those persons who have a knowledge of the practical part, and also of the theory of mining. Such managers have a double advantage, as their knowledge has been practically acquired. They cannot be equalled by any other class of men. Therefore, I would recommend every one in charge of mines to obtain a knowledge of the theory, and also of the practical part.

Son: I think those in charge of mines, father, should be steady,

sober, and attentive, having good knowledge, foresight, and stability, because mines are constantly changing, and things taking place which require much attention and care.—Father: Yes; they should have a good knowledge of mines and mining before they take charge of so many lives and so much property; they should be the men that will go first into a mine when an explosion of fire-damp has taken place. A good manager would not send others where he would not go himself; he will go first, and see the cause, and risk his own life rather than the lives of those under his charge, because others, not having a proper knowledge of their work, and the mode of ventilation, might not do right, from having too great a fear of doing wrong, by which they might cause the loss of their own lives, as well as those they were in search of.

Son: You say it is your wish, father, for every practical man who has got in him the abilities to manage the underground workings of mines (as many practical men in mines, you say, have) to be brought out from the ranks, and for a mining institute to be formed, and that from such institute every one should pass an examination as to his qualification for underground manager. Would you, therefore, have every mining district to call out the men who have got a good knowledge of mining, and give them practical information on ventilation, gases, working out coal, dialling, and laying the workings on a plan, &c., such information being had in their own districts, after which they could be recommended for examination?—Father: Yes, I think it would be well for every district to have days of meeting, for the men to receive information in their own district, to qualify them, as the abilities of a person may be very good, but he may be too poor to often attend an institute which is per-

haps at a distance. After the men have got to a state of efficiency, they should be recommended for examination to the institute, or to some other institute appointed for their examination.

Son: I also think, father, that every one in charge of the underground workings of mines should have a practical knowledge; and also pass an examination as to his qualification and knowledge of mines; a number of lives should not be placed under the charge of a tradesman's son, because he has been able to pay a good premium as a pupil for two or three years. He may profess to know a great deal about mines, but, in truth, it will be very little he will know of them; neither will he be often seen in a mine—his information of them will have to be given to him by others.—Father: If a tradesman's son manages any work, it should be the surface work.

Showing the Mode of Ventilating Mines by Mechanical Power.

Son: Are there not many ways, father, adopted for ventilating mines by mechanical power?—Father: Yes; the ways adopted are numerous.

Son: Can you describe the principle on which mines are ventilated by mechanical power?—Father: Yes; but I shall have to give several sections of plans to illustrate the description.

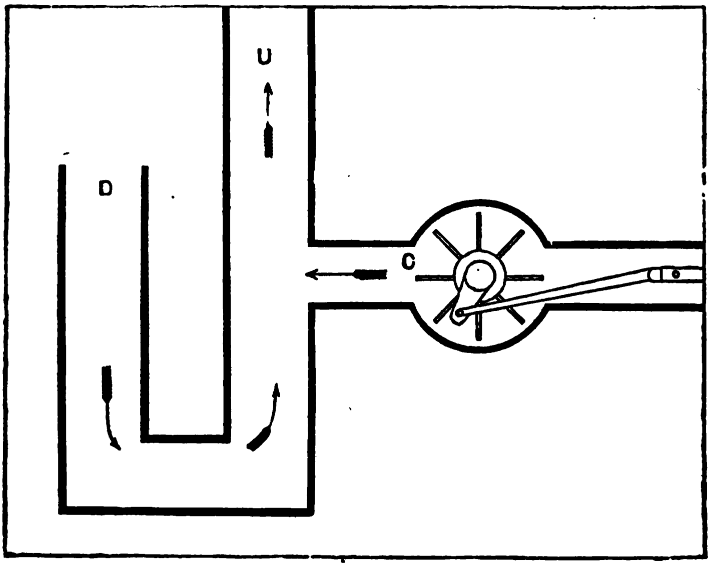
Son: I am glad you understand the principle, and shall be glad to have it explained.—Father: Had I to give you an explanation of the method of ventilating mines by mechanical power, adopted by every person, we should have to continue

here a long time, therefore, I shall only give you one person's views upon it, and that I must show briefly.

Son: Any person's will do; I only wish to see and know the principle.—Father: Then I will give you the late Mr. Wm. Ackroyd's view, of Dudley Hill, Bradford, a person who has for years studied to produce a larger current of air in mines than is now produced by furnace power.

Son: What means of mechanical ventilation did Mr. Ackroyd recommend?—Father: He recommended the up-cast shaft to be walled a few yards above the surface, so as to be a little higher than the down-cast. See section No. 1. D is down-cast and U is up-cast.

Section No. 1.



Son: I think to have the up-cast walled, where it can be adopted, a few yards higher than the down-cast, is a very good plan. What am I to understand by C and the arrows on the plan?—Father: C represents a flywheel so constructed that it answers (as Mr. Ackroyd says) both for a ventilating-fan and a flywheel at the same time. The points of the arrows show the direction of the air-current.

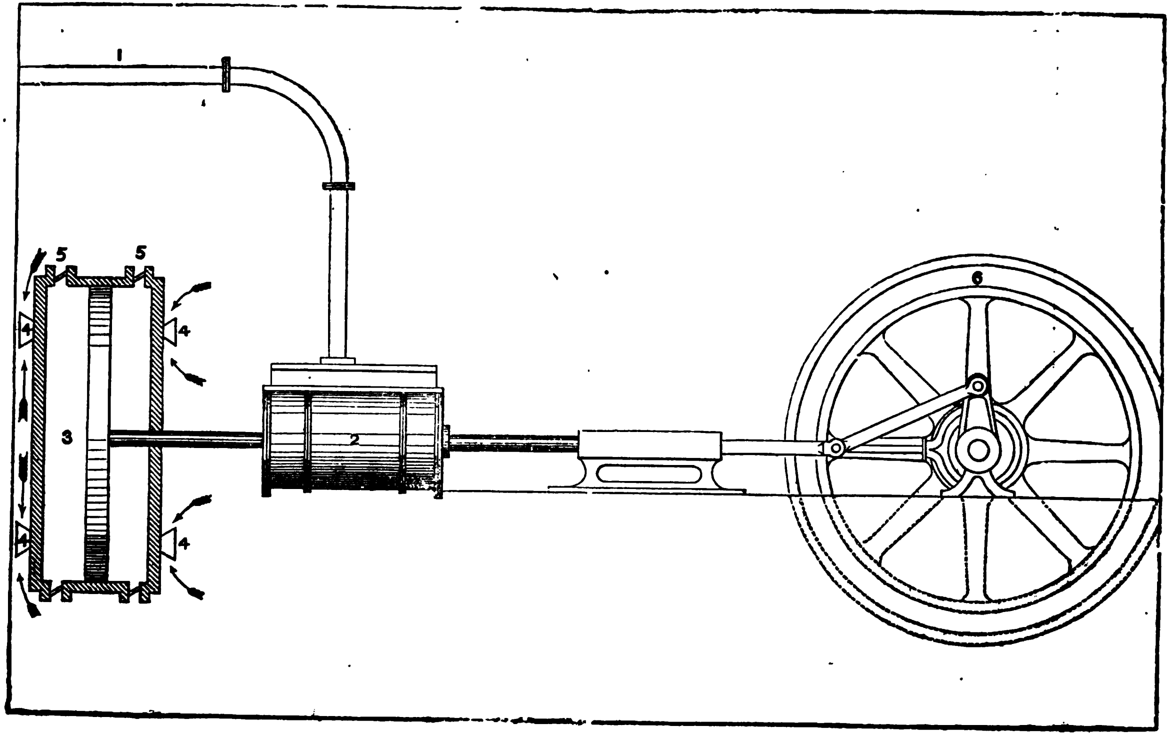
Son: This plan, then, only shows one part of the ventilating engine?—Father: No; another part of it may be seen in section No. 2. The flywheel or ventilating-fan is No. 6.

Son: I think the flywheel would aid ventilation, if it is possible to construct it to act also as a ventilating-fan. No. 1 then is a steam-pipe, from which the cylinder, No. 2, is supplied from the boiler with steam?—Father: Yes, and No. 3 is a large air cylinder, so that when the piston within the cylinder moves backwards and forwards, at every stroke of the engine, the air, ascending the up-cast shaft, rushes into the cylinder through the valves Nos. 4, and out again at the other valves, Nos. 5.

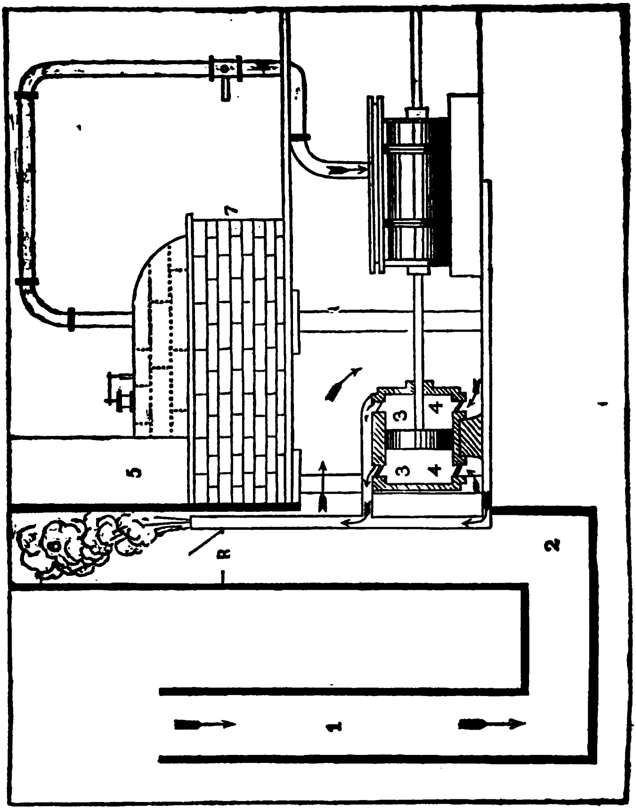
Son: The engine works the ventilating-fan, then, and also the piston within the cylinder, at one and the same time?—Father: Just so. I will next show the boiler, from which the engine is supplied with steam. See section No. 3. In this plan you see the chimney No. 5, the boiler, the air cylinder, and also the steam cylinder. No. 1 is the down-cast; No. 2 the up-cast; No. 7 is the place in which the boiler fire is supplied with coal; and No. 6 is the place where the heat, the steam, and the air propelled by the engine all meet, to ascend the up-cast.

Son: Then does Mr. Ackroyd profess to have for his ventilating powers the air cylinder, the heat from the boiler-fire, the ventilating fan, and the steam from the engine?—Father: Yes,

Section No. 2.



Section No. 3.



and he also states he has always the natural draught for another power.

Son: Always the natural draught in mines. I understood you to say that there was not *always* a natural draught; and do you not remember, father, four of us surveying the underground

workings, at a colliery in this district, on Monday the 3rd of July 1873, when it was proved that *no* natural draught was in the mine, as the smoke from the burning rope rose direct to the roof, the furnace fire having been out, you know, a few days.—Father: Yes, I remember it; I yet say, there is no natural draught in mines on hot days in summer. You may try to convince a man against his will, but he will be of the same opinion still.

Son: What am I to understand then, father, by the letter R on the plan?—Father: Mr. Ackroyd's opinion is, that the ventilating powers will be *so* strong, as to force all the air up the shaft; but my opinion is, that the up-cast shaft will *have* to be *inclosed* at the letter R, to *prevent* the air and steam, propelled by the engine out of the pipe, returning down the shaft back again to the air-cylinder.*

Son: Why do you think the air will return down the shaft again through, at the letter R, to the air-cylinder.—Father: Because the rush of air *into* the cylinder is a *power below*, and not above R. The cylinder does not propel air up the shaft through at R, but is a power below, taking in air, and receiving its supply of air from the nearest point. Therefore, if the shaft is not inclosed at the letter R, there is nothing to prevent the pressed air, propelled out of the pipe, returning down the shaft again to the air-cylinder. Also, in passing the air through the workings, it may have a long distance to travel, and much friction in its route; but the distance and the friction is *very small*, from the exhausted pipe *through* at the letter R, to the cylinder. That is why I think the cylinder *will* receive back over and over again *part* of the exhausted air, *unless* inclosed at the letter R.

* I only give Mr. Ackroyd's views, not that I agree to all stated.

I do not say *all* the air will return, but my opinion is that part of it will.

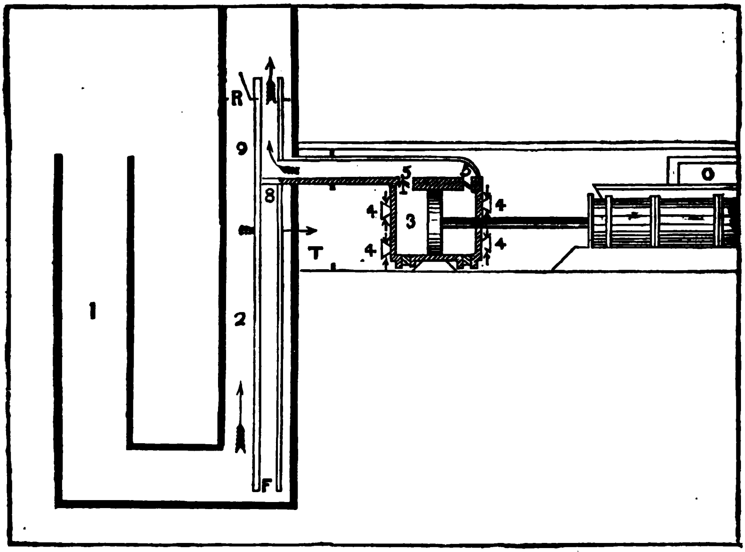
Son: You only give your opinion then, father, and allow Mr. Ackroyd to have his opinion also?—Father: Just so; yet my knowledge of the *laws* of nature tells me that if it were not as I believe, I should be much surprised. Such views I showed Mr. Ackroyd in a letter, to which he gave the following reply—"You seem to think that, except the up-cast were covered over, the air, after being exhausted at the pipe, would return down the shaft back again to the air-cylinder, in spite of the high temperature got up by the air furnace and boiler fire, and in spite of the force of air and steam forced out of the two cylinders by the power of the engine, and in spite of the expansion of the air and steam, and also in spite of the extra pressure of the air at the top of the down-cast over that of the up-cast, but it would not return from the pipe to the cylinder again."

Son: In what part of the up-cast, then, is the ventilating engine fixed?—Father: My opinion is, that any part will do, if only the external air is *prevented* from getting to it. A space sufficiently large in the side of the up-cast, a little below the surface, Mr. Ackroyd states to be the best.

Son: Have you any more plans to illustrate the mode of ventilation by mechanical power?—Father: Yes. See section No. 4. You see the engine, the two cylinders, and the valves. In this there is also an air-pipe in the up-cast. See No. 8 This pipe extends from the top of the shaft to the bottom.

Son: Just so. I see the pipe, but what am I to understand by No. 9?—Father: At No. 9 a valve might be fixed in the pipe so as to close it in case of an explosion in any part of the workings. The object of a valve being fixed there is to *turn* on

Section No. 4.



the air *down* the pipe from the cylinder into the exploded part.

Son: I understand that, father, very well; but I wish to know the place from whence the cylinder will receive its air to supply the pipe with fresh pure air for the exploded part. Will the cylinder gets its supply of pure air from the top of the up-cast or from the bottom? If supplied from the up-cast, will it not be propelling down the pipe *impure* air to return back again to the place from whence it came, so that it would be working over and over again the same impure air? And if the cylinder is supplied with pure air from the top of the up-cast, I wish to know the outlet of that air propelled into the workings through the pipe, or, in other words, the up-cast for it.—Father: You see a letter O on the plan, do you not?

Son: Yes.—Father: Well, there is a door at or near the letter O, through which there is a passage to the surface; also there is another door fixed at the letter T, between the up-cast and the air-cylinder. So that in order to supply the air-cylinder with pure air, when an explosion takes place, all that is required is to open the door at O, and close the door at T, and, by so doing, the air will pass down the pipe pure, from the surface to the exploded part, and the impure air will go to the up-cast shaft.

Son: Very well, I can see now, father, into the principle of it. I also see a letter F in section No. 4, at the bottom of the pit or pipe. What do I understand by that?—Father: At the bottom of the pit and into the workings there are laid four air-pipes, east, west, north, and south, all of which join the pipe F. See section No. 5.

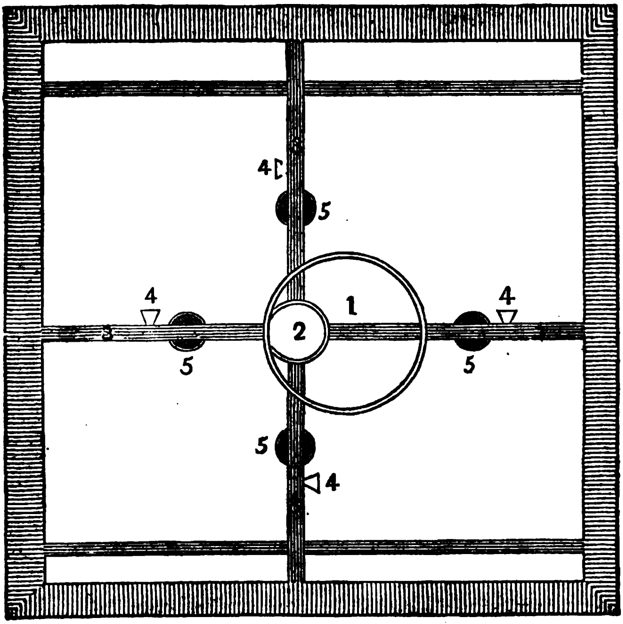
Son: I see all the four pipes, father, in this plan.—Father: The large circle, No. 1, is the pit-shaft; No. 2 is the end of the pipe to which the pipe F, in the other section, is fixed; Nos. 3, 3, 3, 3, are the four pipes which branch out and are laid on the roadway into the workings.

Son: I see now well how the pipes are laid; but suppose an explosion took place in one of the working parts, how or by what way would all the air, in the other three pipes, be turned into that one exploded part?—Father: You see Nos. 5, do you not?

Son: Yes.—Father: Well, those are stop-cocks fixed in the pipes. All that would be required is to turn off the air from three of the pipes, and, by so doing, the whole pressure of air in them would be turned into the one pipe in the direction the explosion had taken place.

Son: I see now how all the air might be turned into the

Section No. 5.

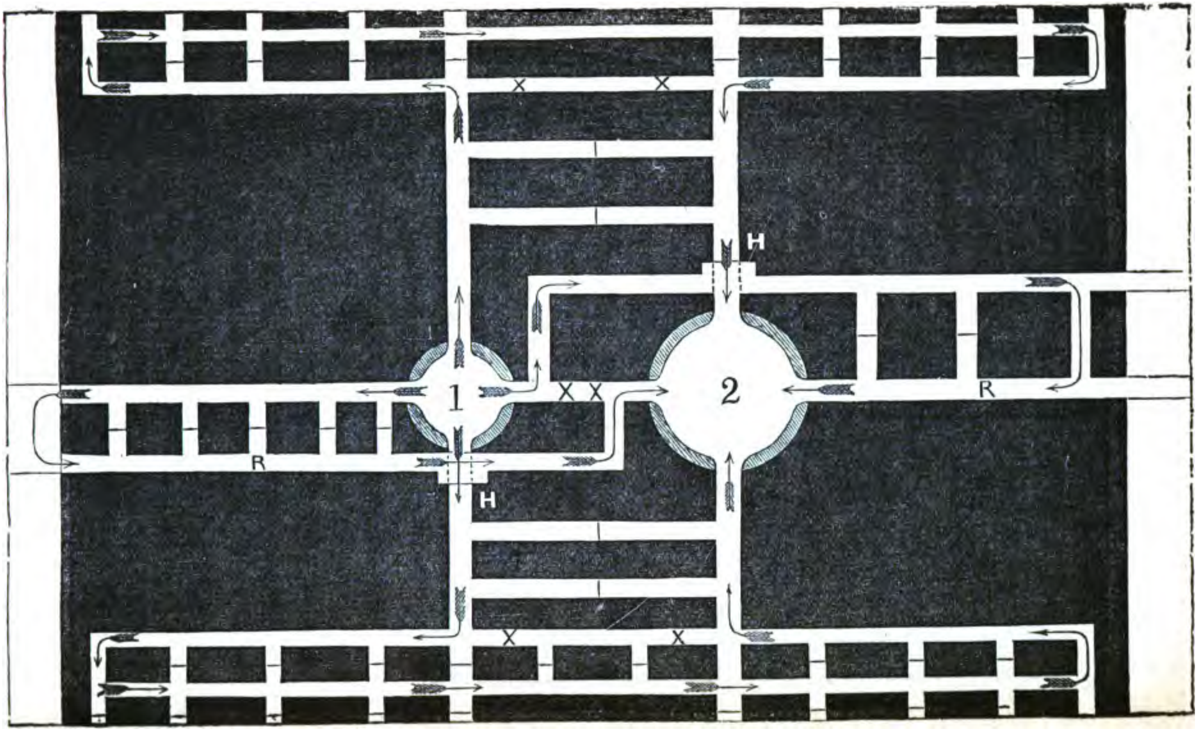


exploded part.—Father: Yes; but Mr. Ackroyd shows, also, how those pipes may be used to speak through from the down-cast to the surface, and from the surface into the workings.

Son: Pray how is that accomplished?—Father: In the following manner. You see, do you not, Nos. 4 on the section.

Son: I do.—Father: Well, those are mouth-pieces through which to speak to people on the surface or in the workings. By closing the stop-cocks, the sound of the voice can be sent into the direction required.

PLAN No. 6.



Son: That, father, is very good; have you any more plans? —Father: Yes. I will show you another plan of Mr. Ackroyd's, and then I have done. It will be a plan on separate currents of air for the workings. See plan No. 6. This plan is very good. You see the up-cast, No. 2, is much larger than No. 1, the down-cast.

Son: Is the shaft larger because the air expands when made hot, and by the up-cast being much larger, room is allowed for the expansion of the hot air?—Father: Yes. There are also, you see, four separate divisions of air direct from the down-cast shaft. Those four divisions all come into the up-cast in four separate parts or divisions.

Son: By what you have said to me before, you strongly recommend that mode of ventilation, and the up-cast being larger than the down-cast. But what am I to understand, father, by the letters H, X, and R, on plan?—Father: The letter H shows where the impure air from the workings crosses the pure air. The letter R shows where the air requires regulating. The letter X shows where doors are fixed to allow the tramboy to pass and repass into the workings.

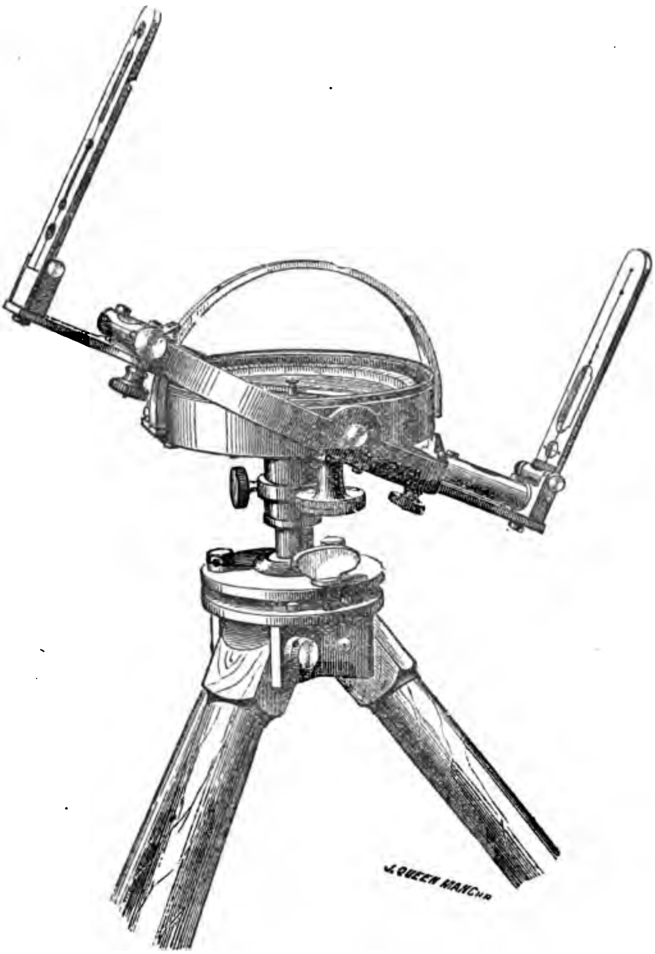
Son: Very well. I am glad for your explanation how mines are ventilated by mechanical power, only you do not agree, you say, with everything stated by Mr. Ackroyd.

The Mode of Dialling.

Father: A knowledge of land and mine surveying, and also of planning, is very useful, a subject every manager should understand.

Son: I should think so. Is this then a dial? (See next page.) —Father: Yes: it is made by Casartelli, 43, Market-street, Manchester, with the latest improvement which has just been accomplished by him. Mr. Casartelli, in 1861, improved the miners' dial, by mounting the limb which carries the sights on axes or trunnions, cast on the comp ss box, attaching the arc for giving the angles of inclination to one of the trunnions, with the index so fixed as to be moved by the sight-limb whenever it was inclined to look through the sight up or down the road, thus giving the angle of *rise* or *dip*. This worked well, but it was necessary to take off the arc every time the dial was put in its case, and to fix it on the dial whenever it was required, and it sometimes happened that when wanted it was in the case in another part of the mine. To obviate this inconvenience, Mr. Casartelli recently introduced a semicircular limb, fixed to the compass box by pivots in the line of N. & S. in such manner as not to obstruct the view through the sights; the degrees of angle are graduated on the face of the semicircle, and read off by indexes attached to the sight-limb, and which ride over the face of the semicircle when the limb is inclined for the purpose of taking a sight in steep mines. When the arc is not required, it is simply folded down on the outside of the compass box, between the latter and the sight-limb. By this improvement the moveable quadrant is done away with and all its inconvenience; the present semicircular arc is always at hand when required, and it can be put in or out of use in an instant.

Son: I think such a dial is very convenient. Father: Very convenient for mine surveying. The needle may be either used or dispensed with, and used as a theodolite, and by it take the dip of the mine also.



Casartelli's Latest Improved Circumferenter, or Miner's Dial.

Son : There are several kinds of dials, I think, are there not ?—Father : Yes ; I will show you others, but I think the one you see the most useful.

Son: You say, father, underground managers should have a knowledge of dialling, and drawing the workings of a mine on plan. I wish to know how you would have them to get this knowledge, as few persons will show a miner intending to improve himself so as to become a mine manager how it is accomplished, be his abilities ever so good ?—Father: I know few persons will show a man with a practical knowledge of mines how it is accomplished. It cost me a great deal of money, and I had much to do to prevail upon a person to give me the information ; I have often had letters from practical men asking for information as to how it was accomplished, and I have been sorry not to have been able to give them that information by letter that I could have done had I been in their company; the knowledge must be got by practice—seeing and doing the work. It is difficult a little to understand and get a knowledge of it by reading and hearing.*

Son: Would it take a long time for a person to get the necessary knowledge ?—Father: No. It would soon be obtained if those who wish to acquire it could only have a little practice.

Son: But I fear no one, father, would show a number of underlookers and deputies the way by which dialling is accomplished in mines ; they would not take the dial into a mine and show them.—Father : There is no reason why they should take it into a mine to obtain this knowledge; the information can be

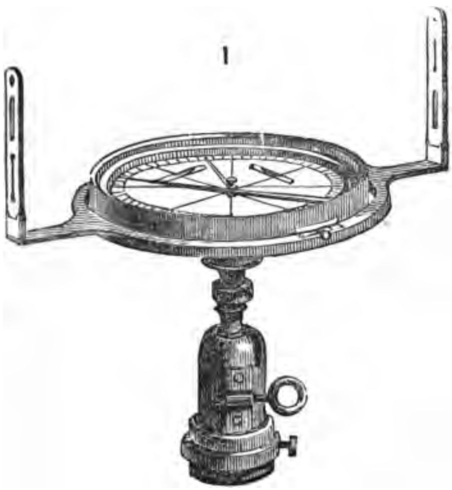
* The knowledge of mine surveying and planning may be understood by reading this Conversation on Mines. Several persons have written to say that they are able to survey the workings of mines, and lay the same on plan, by reading the contents of this book. I might name two persons out of many, Mr. W. Hitchin, underlooker, of St. Helens ; and Mr. Wm. Valentine, underlooker, of Wigan.

got on the surface; and a person would very soon understand how it was accomplished in a mine, he having a practical knowledge of the underground workings.

Son: I should be glad to know and understand the mode of dialling, and laying the workings of a mine on a plan, if you can give me that information.—Father: I hope to give you knowledge how to survey mines with the compass and the theodolite, and also of laying the workings of a mine on a plan, if you will attend to what I have got to say, and inspect the figures I shall show you. The figures will give you a better knowledge, as I shall give an explanation of them.

Son: Be assured, father, it will be my endeavour and delight to attend to the instructions you give, as I very much desire to know how to dial, and how to lay the workings of a mine on a plan.—Father: The diagram you see is another representation of a dial; you look at objects through the upright sights.

1



Son: Then this is also a dial. I see no figures on the dial plate.—Father: You may not see the figures in its *present form*, but I will show you it in another, to enable you to see the figures. In the large plan you will see the dial in another form; see No. 14, at the beginning of this book.

Son: Yes, father, I see, and I think I shall be able to understand the figures better now.—Father: Figure No. 14 is a representation also of the compass or dial. There are, you see, figures "around" the outer circle which give the number of degrees around the circumferences of the dial. You will see, also, figures around the inner circle; these give the number of degrees between north and east; and also, between north and west. It will likewise give the number of degrees in the quadrant, that is, between south and west, and between south and east. For example, there are 360 degrees around the whole outer circle of the dial, but between north and west in the inner circle, there are 90 degrees. Also 90 degrees between north and east; 90 between south and west; and the same number between south and east.

Son: I see there are, father, two rounds of figures on the dial; those figures around the whole outer circle show 360 degrees; but those around the inner circle show 90 four times repeated. —Father: Yes; so that when you read off those 360 degrees around the outer circle of the dial, you will have to make an entry of the number, whatever it may be; but if you wish to know and make an entry of the number of degrees between north and west, or between south and east, you will have to read off those degrees or figures around the inner circle of the dial, and give the number of degrees between north and west, &c., whatever that number may be.

Son: Dials are not all figured alike, are they?—Father: No. Some are figured round on the left, similar to the dial shown in the large plan, fig. 14, others are figured round on the right, similar to the figures on a clock face, commencing at 1, 2, 3, to 12, and so on to 360.

Son: If dials are not figured all one way round, protracters will not have to be figured all one way, will they?—Father: No. A protracter (to be suitable for a dial) should be figured round on the opposite direction to the dial.

Son: Then if I find a dial to read off on the right, a protracter to read off on the left will be suitable to the dial; but if I find a dial to read off on the left, my protracter must be read off on the right?—Father: Just so. If you only attend to this, you will be able to survey with any dials.

Son: Very good, father, I understand the figures on the dial, but what about the dial needle? I see it vibrates, or works backward and forward at every turn or movement of the dial.—Father: The cause of the vibration of the needle is, that it is a magnetic needle, which is balanced upon the point of a pivot, so that it can vibrate without friction towards the direction to which it is most attracted. Its tendency is always to point towards the north. That is to say, the needle may vibrate backward and forward when the dial is removed, but it will soon come to a stand-still when the dial is at rest, and one end will point north, and the other, of course, south. We learn from observations that the needle does not always point to the same place; there is a slow, but almost continual variation, which does not appear to be capable of previous calculation. Thus, in the year 1576, the variation from true north was 11° 15′ east; in 1657, the needle stood due north; in 1803, there was a west variation of 24° 59′;

in 1820, the variation was about 24° 12′ west, and from that time to August, 1864, the needle has varied to the east about 3° 40′. The variation in the beginning of 1868 was 20° 15′ W. Generally, it may be understood that the western declination is now diminishing at the rate of 1° in eight years. When the survey of underground workings is performed by the compass, it is well to have the meridian lines which are drawn on a plan dated, by which means the variation can be got, so that in every subsequent survey, if the variation be different, the meridian used in plotting can be altered accordingly.

Son: Suppose, father, I take the dial, and place it at any point I may think proper, and look at an object at a distance; how am I to fix the dial so as to ascertain the degree north or south of the object, from the situation of the dial?—Father: Before I proceed to show you how to fix the dial, and to understand its indications, I would beg of you to have a look once more at the dial. You see (on the large plan No. 14) a letter N next to one of the sights, and also a letter S near the other sight. Well, when you fix the dial, always have the sight N next to the object you look at, and look through the sight S. That is in going forward. If you fix a dial in a mine, see and always have the sight or letter N next to the working face, and the sight S next to the pit from whence you go, looking through the sight at objects which convey you from the pit into the workings, and so continue to look through at the letter S, sight after sight, until you come to the working face; but if in case you take a back sight [at an object towards the pit, keep the dial in the same direction, looking through the sight at the letter N:—that is, keep the dial fixed so that the sight at the letter N will always point into the workings, and the sight at S will point to the pit.

Son: Very good; I am glad, father, for the information as to how to fix the dial, which, I think, I now thoroughly understand; but how am I to know the number of degrees between one object and another?—Father: You must fix the dial in the way described, and look at objects through the sight S (if such objects convey you from the pit into the workings); after the needle has come to a perfect stand-still, look at the north-end of the needle (as one end always, as before stated, points north, and the other south), and see what degree the point of the needle is at, and whatever the figure may be, make an entry of it in your book, for it is the number of degrees away from the north to the object.

Son: Suppose the north-end of the needle should stand at 63½°, will it be 63½° north-east?—Father: Yes. The degrees between north and east are the same in this case as those degrees around the outer circle of the dial, yet it is not requisite at all times to make an entry in your book of the two rounds of figures. I only give you a knowledge how to read off the dial by two ways, so that, if required, you will be able to read it off by either way; that is, you will know the dial by its degrees between north-east or south-west, &c. Yet, as you are only a learner, you will understand the degrees of the dial much better if you only make an entry of the outer circle of figures.

Son: Then if I find the point of the needle stands at, say 63½°, when looking at an object, all I have to make an entry of in my book is 63½° to the object? But what am I to understand by these 63½°?—Father: Well, the point of the dial needle always stands or points north, therefore, 63½° is so much away from that north point; that is, you will have turned the sight letter N away from the north point of the needle so far, that a space of 63½° will be between the north end of the needle point and the sight N.

Son: Then if I look at another object through the sight S, and the north-end of the needle stands at 125 degrees, I have only to make an entry of the distance in my book and between object and object?—Father: That is all you have to do. If, on looking at another object, the needle is at a stand-still at 152 degrees, it only shows a greater space between the sight N and the north point of the needle. And in like manner you may continue to look at objects in several directions, and every object looked at may vary in the number of degrees, more and more until you come with the sight N round again to the north point of the needle. Therefore, an object at 152 degrees would be in the south-east direction at 28 degrees, that is, it would point 28 degrees away from the south-eastward. And in like manner an object at 240 degrees would point in the south-west direction, at 60 degrees between south and west. If you look at an object at, say 320 degrees, the needle point would be at a stand-still at 40 degrees in the north-west direction. There is no necessity (as before stated) for you to bewilder yourself when dialling by making an entry in your book of the two rounds of figures, unless you think proper; the figures around the outer circle of the dial will do.

Son: I think every person, father, may understand how to fix a dial, and also make a proper entry of the degrees, after being informed in this way. But how would you commence to dial the underground workings of a mine?—Father: Suppose you are required to dial workings similar to those on figure 15; you may make, if you think proper, a sketch in your book similar to figure 15, or according to the roads cut in the mine: after which, fix the dial in any part of the road, so as to enable you to see the centre of the pit and along the tram-road forward to

the cross-roads. At the same time, let the dial be so fixed that the letter or sight S will be next to the shaft, and the sight N next to the working-face, always keeping the dial in the manner described; then look forwards through the sight S, but if you have cause to take a back sight towards the pit, look through the sight N, and after the needle has come to a stand-still, make an entry of the number of the degree pointed to.

Son: Suppose, father, I find the north-end of the needle point to 63½ degrees?—Father: If so, make an entry on the sketch in your book, similar to the one you see on the figure; you see it shows 63½ degrees, so that it is 63½ degrees north-east. Afterwards measure the length from the pit to the cross-roads.

Son: Suppose I find, father, the length of the road to be forty-five yards?—Father: Then mark forty-five in figures, similar to those you see on the sketch.

Son: The length, father, being finished, do I remove the dial forward to another object?—Father: Yes; and fix it, if possible, in the centre of the cross-roads, so that you may look forward and into each side road without removing it; but, if you cannot so fix it, on account of iron, towards which the needle is attracted, each road will have to be taken separately, in the way you took the first length from the pit.

Son: Suppose I fix the dial and look forward on the first road, and find the north point of the needle to point at 61 degrees, and the length from the cross-road to the end of the road is forty yards, and I look for the degrees on each side-road. One road I find at 152 degrees, and the other at 332½; all I have to do is to make an entry of the figures with the length of each road, one of the lengths being, say forty-five yards, and the

other twenty-two yards.—Father: Just so. That will be the way with the degrees around the circle, but those degrees of the quarter circle, or quadrant, will be north-east 61, south-east 28, and north-west 27½ degrees.

Son: Then the sketch in my book will be like figure 15?—Father: Just so. Now you have a knowledge of dialling, or how to read off the dial: and if you only attend well to it, you cannot but know the direction of each working part of the mine, and be able to dial forward as the workings of the mine extend, following on from sight to sight, until every sight is dialled from the pit to the extremity of every road in the whole mine.

Son: As I have got a knowledge of dialling, I now wish to have a knowledge, father, how to lay the workings of a mine on a plan; that is, if I had a large sheet of paper, I wish to know on what part of the paper to fix the pit, and how to commence laying the workings?—Father: All you have to do is simply to place upon the paper a mark similar to the letter O, and call that the pit; you may fix the pit on any part of the paper, but as near the centre as possible will be best.

Son: And what have I to do, after fixing the pit?—Father: You see a line drawn across the pit in figure 16, do you not?

Son: Yes I do. I also see at one end of the line a letter N, and a letter S at the other end. The line passes directly across the centre of the pit.—Father: Well, after you have fixed the pit on the paper, draw a line across it similar to the one you see in figure 16.

Son: I am quite able to do that, but what shall I do after?—Father: What you have next to do is this:—take your protracter and place it across the pit and line, after which, it will be similar to figure 17.

Son: Very good. I am able, also, to do that. I see figure 17 is only a representation of figure 16, with a protracter added to it; but what have I to do, father, after fixing the protracter?—Father: You have only to look into your book (figure 15) for the degrees from the pit to the cross-roads. Did you not make an entry there of 61½ degrees from the pit to the cross-roads?

Son: Yes, the number of degrees are, I see (figure 15) 63¼, and the length of the road is 45 yards.—Father: All you have to do, then, is to count round from the north end of the protracter until you come to 63¼ degrees, and there make a pin mark (see P) in the side of the protracter.

Son: After I have done so, do I then take up the protracter? Father: Yes, and measure from the centre of the pit, forward in the direction of the pin point, the length of the road, 45 yards, on a scale of 20 yards to the inch.

Son: After measuring the length of the road, will it represent something like figure 18? as I see the road extends beyond the pin mark P.—Father: Yes, and by this you have got the pit, and the first length upon the plan.

Son: I can see very well, I want the cross-roads; now, what have I to do next to lay them on the plan?—Father: All you have to do is simply to make another line with your pencil across the end of the road, similar to that across the pit. This line must be parallel to the one across the pit; to make a correct line you will require a parallel ruler. See figure 19.

Son: Figure 19, I see, is only a representation of figure 18, with a parallel ruler upon it, which ruler must be opened out until a line can be drawn across the end of the road; and what have I to do after?—Father: You have to take your protracter

again, and place it across the road, placing it in a similar manner as you did across the pit (see figure 17).

Son: When I have done so, it will, I see, represent something like figure 20, as the protracter is upon the line N and S.—Father: Such is the case. You will have to look again for the degrees in your book (figure 15); there are for one road 61, another 152, and the third road 332½; such are the several degrees in each road.

Son: Then I presume, father, I have only to do as before, count round the protracter for the degree on each road, and make a pin mark at every degree?—Father: Yes: you count round the protracter until you come to 61, then make a pin mark at P, after which count again until you find 152, and there also make a pin mark at P. Count forward to 332½, and make another pin mark there.

Son: Very good; I see, father, all the pin marks around the edge of the protracter; do I now lift off the protracter?—Father: Yes. You take off the protracter, after you have done so it will be similar to figure 21. See all the pin marks P.

Son: Well, father, I think I can see a little how planning is accomplished: I have only to measure separately each of the roads, measuring from the end of the road direct to each pin mark. The measurement of one road is forty yards, or two inches on the plan; the other roads are twenty-four yards and twenty-two yards.—Father: That is the way; make the length of each road according to the scale, and also according to the number of yards you have entered in your book.

Son: When I have got the length of each road on the plan it will, I see, be like figure 22.—Father: Yes, it will; you must continue to lay the workings on the paper until the whole of them are finished.

Son: Is there not another way, father, by which workings may be laid on plan?—Father: Yes, all you have to do, is to place the pit on your plan similar to the letter O, the pit may be marked on any part of the plan-paper, if only you have space for the workings, therefore, near the centre of it is the best. Also the meridian line should not, in this case, be marked across the pit, as before, but marked on the paper in any part best suitable.

Son: If the pit be marked in one part of the plan, and the meridian line in another, how do I proceed to lay down the workings?—Father: All you have to do is to place the protracter on the line similar to figure 25, page 162, after which mark off all the degrees entered in your book.

Son: The degrees entered, I see, in my book are as follows: 1st sight 90 degrees, and the length 11 yards. 2nd sight 80 degrees, length 8 yards. 3rd sight 50 degrees, length 14 yards. 4th sight 100 degrees, length 19 yards. I find the next sights point into another direction; because the 5th sight is 300 degrees, length 19 yards. 6th sight 345 degrees, length 33 yards.—Father: Those are the lengths and number of the degrees named, therefore, if you look at the protracter (figure 25) you will see all the degrees marked, and in laying down the degrees of the roads in a mine they are marked round the protracter in a similar manner to figure 25, page 162.

Son: Now that all the degrees are marked, do I take away the protracter?—Father; Yes, take it away. See figure 26 with all the pin marks at each degree. Figure 26 is only a representation of figure 25, only the protracter is removed.

Son: I see all the pin marks: how do I commence to lay down the workings?—Father: You know the first sight was at 90 degrees, and the length 11 yards.

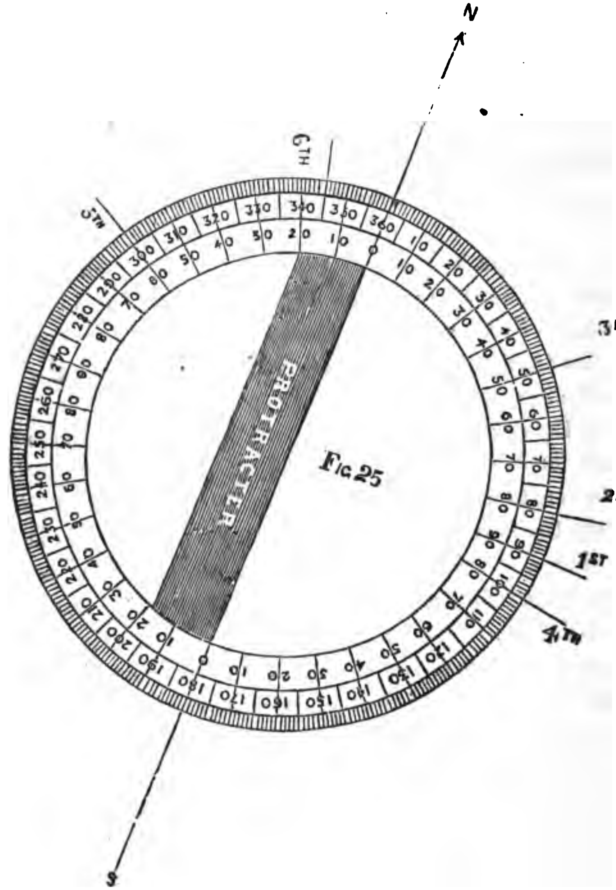
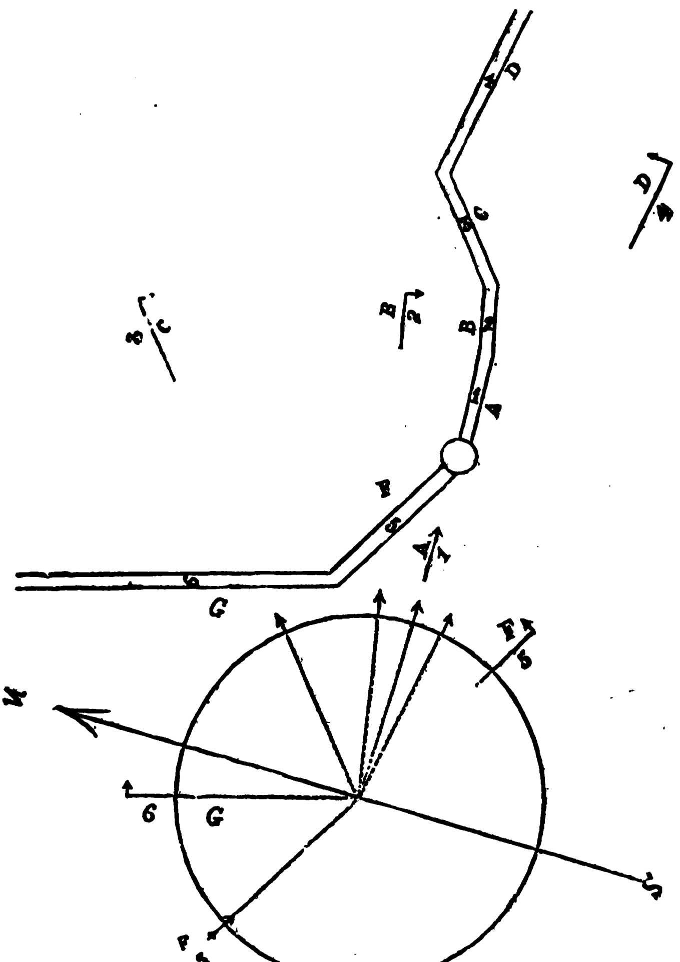


Fig. 25

Figure 26.



Son: I do, and a pin mark was on the protracter at 90 degrees. This sight was No. 1, see, it is parallel with A A, and the first length of road from pit.—Father: You are right, and so each sight is also parallel with the following numbers and letters, and also, each of which is parallel with the degrees of the road. The second sight is also parallel with the letter B; the third sight is also parallel with the letter C, and so is each sight parallel with the road.

Son: Then I have only to open out the parallel ruler, to make each degree parallel with the road?—Father: That is all you have to do, except to mark down the length of road between each sight.

Son: I see very well now, father, how to lay the workings down on plan by this mode of plotting. There is no cause to make a meridian line at the end of every sight, as required by the other mode of plotting.—Father: No, there is not: the degrees entered in your book can all be marked off at once by this said mode. See figure 26.

Son: I may, I presume, father, in a similar manner, lay fields, boundaries, &c., if I only commence, say at the pit, and look towards such objects? — Father: Yes; you may in the same manner lay on the plan any boundary or field, if only the pit or any well known object be the place at which you commence; you first lay the pit on the plan, and therefore it must be the object to commence from to find others, or any other known object will do.

Son: I am very glad, father, for the knowledge of dialling, and also of laying the workings of a mine on a plan. I wish now to understand the mode by which I may take the dip and rise of the mine? — Father: it is my intention to give you that

information also. You see figure 23, on the large plan at the beginning of the book, which is a representation of a dial; on the dial cover you will find figures similar to those in figure 23; you will also find in the cover two holes, as represented in figure 23. All you have to do is to fix a peg, as in figure 23, with a string to which a weight is suspended.

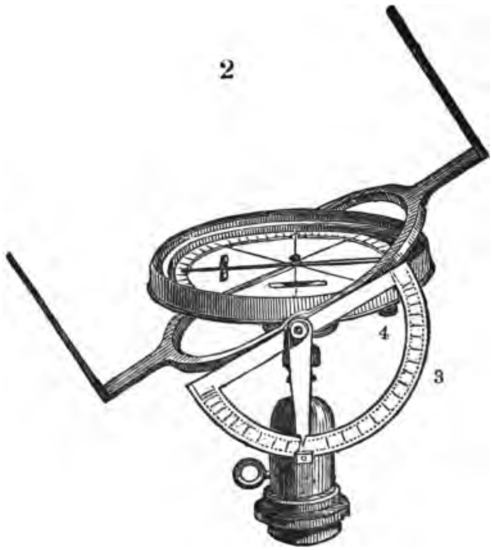
Son: Shall I not have to fix the dial on one side, and look through the sights when it is bent down?—Father: Yes; and when you look through the sights at objects downwards or upwards, so will you be able to find the degree of such dip or rise of the mine.

Son: I see, father, the string on the dial cover is at 17; do I understand that to be 17 degrees?—Father: Just so. The mine dips at an angle of 17 degrees. All mines do not dip so much; some dip more, others much less; 17 degrees is about the dip here (St. Helens).

Son: Do I lay the dip of the mine on a plan similar to the one of the underground workings?—Father: Yes. All you have to do is to make a straight line on your plan, and call the straight line the level surface (see figure 24), place your protracter upon this line, and count round to 17, make a pin mark there, and then take up the protracter.

Son: Then I see the dip of a mine will be shown in the same manner as in the large plan, fig. 24?—Father: Just so. You will now, I think, understand how to take the dip and rise of the mine. There is another construction of a dial, by which you may take the rise and dip of the mine. (See the diagram.) It is so constructed as to suit the declivity of the mine.

Son: This dial is, I think, very convenient. You will be able, with a dial like this, to take the degree of the road, and the



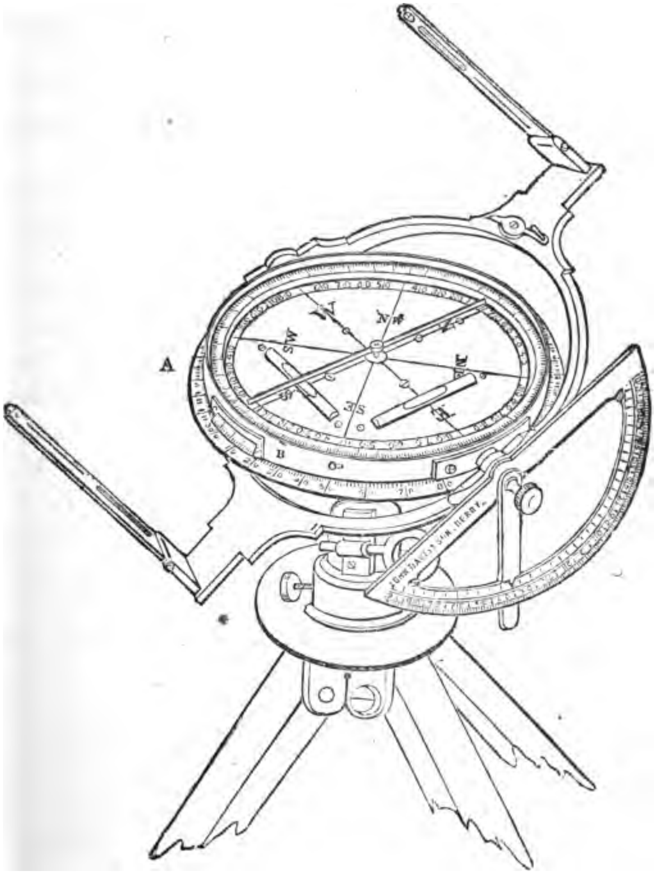
dip or angle of it, at the same time.—Father: Yes; the dial is very convenient. It is Headley's dial, but manufactured by Mr. Davis, of Derby, the manufacturer of mining instruments.

Son: You have got here I see another of Mr. Davis's dials. (See page 167.)

Father: Yes I have. This dial is a very useful instrument, it combines all the latest Headley, with the outside vernier of the theodolite.

Son: This dial, manufactured by Mr. Davis, of Derby, must be much improved, and also very useful for mine surveying.

Father: So it is. The figuring is so arranged that the readings of the needle and the vernier tally, thus keeping one another in check: If the needle be used, the vernier will detect the slightest


A
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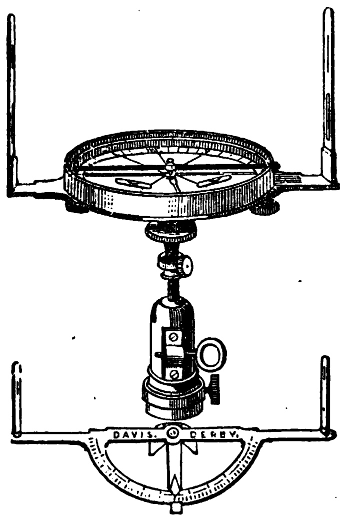
local attraction, and that which has hitherto been doubtful in mining surveying will, with this instrument, be certain of accuracy as far as the magnetic bearings are concerned, which heretofore could only be checked by a repeated survey.

Son: The Headley sights and the vernier plate on this dial, may, I presume, be clamped, and the dial can then be used as an ordinary rigid one, can it not?

Father: So it can. One great advantage of this construction is, that if the dial be out of adjustment, it is at once detected by comparing the vernier and needle readings.

Son: But in reference to its weight with others?—Father: Its weight is not more than that of the ordinary Headley, and it is equally compact. Here is also another form of dial, similar to Headley's, which are attached at pleasure, for ascertaining the angle or dip.



Theodolites for Mine Surveying.

Son : The theodolite is used now, is it not, father, for surveying the underground workings of mines ?—Father : Yes : some people make use of it.

Son : Is the theodolite very difficult to get a knowledge of?—Father : You may soon know how to use it for the surveying of mines, it is very simple.

Son : I desire much to know how to survey mines with the theodolite.—Father : It is my intention to give you also that information.

How Theodolites are constructed.

Son : I shall be glad first to be informed how theodolites are constructed.—Father : I might give you a minute description how several theodolities are constructed, but to do so would, I fear, only bewilder you ; therefore, my object will be to give the *principle* on which they are constructed. Theodolites are similar to dials, with upright sights, through which you look at objects. Around the circular-plate are engraved 360 degrees. The upright sights are so constructed that in moving them round, like the hands upon the face of a clock, you do not, at the same time, move the circular plate. Therefore, in moving round the sights to look through at an object, you take particular notice of the degree opposite the sights.

Son : I can see, in my mind's eye, the principle upon which theodolites are constructed. The minute-hand on the face of a clock is moved round from the hour of twelve to one, and from thence to two, and forward round again to twelve. So also, I see, are the sights on a theodolite moved round from 0 or zero ; if you

think proper, you may say from the north point on the theodolite-plate.—Father: I am glad you see the principle on which theodolites are constructed, you now require a knowledge how to use them.

The Magnetic Needle dispensed with, and how laid on Plan by that Mode of Surveying.

Son: Just so, that is what I wish to know; but I would first ask, is the magnetic needle entirely dispensed with in surveying mines by theodolites?—Father: The magnetic needle can be dispensed with entirely, if only the datum line can be found, that is to say, if you can find—say due north from the centre of the shaft—into any part of the workings; if not, you will have to use the needles for one length only, to find the direction from the pit-shaft into the workings.

Son: Well; but you know, the underground tram-roads vary, not being worked in a straight line; and if you dispense with the needle, how will you know the proper degree, or the proper direction from the pit shaft into the workings?—Father: The degree or the direction of each tram-gate into the workings, is very well known by the use of the theodolites. There are two ways by which mines may be surveyed with theodolites; yet the two ways of surveying are nearly alike. In both ways you lay the workings on a plan, just the same as when surveyed with the dial or compass. The only difference in the one from the other is—you do not require to use the parallel ruler to make, at the end of each sight, a meridian line.

Son: I do not require to make a meridian line, at the end of every sight, then how do I lay down the workings? Do I not

use the protracter, as used in the other way of laying workings on a plan?—Father: You make use of the protracter.

Son: If I use the protracter, upon which line do I lay it, to find the degree, or the next angle of the road? because in the other mode of planning, I lay the protracter, you know, upon the meridian line.—Father: In laying the working down, so as to find the angle of each sight, you have only to place the protracter upon the line which you make from sight to sight; by so doing, you are enabled to find the angle of the following sight, whatsoever it may vary from that on which the protracter is placed.

Son: I see very well, now, how this is accomplished. Each line of sight, or tram-gate line, is similar to a meridian line, in finding the next angle of the road.—Father: Just so. That mode of planning is adopted when you take the angle by one way of surveying by the theodolite, but not by the other.

How Mines are Surveyed by Theodolites.

Son; I wish to know how to use the theodolite by the two ways, therefore, I think, you may show the latter mode first.—Father: I will do so. I gave a description, you know, of the theodolite, or the principle on which it is constructed; this I wish you to bear in mind. Then, suppose we take the theodolite into a mine, and commence to survey with it, from the pit along one tram-gate, into the workings. Again, suppose the first sight is known to be, from the pit, due north, and the length of the first sight, say 100 yards.

Son: Well, say it is due north.—Father: If so, all we have to do is, to fix the theodolite in the tram-gate at the 100 yards mark, with the sights thereon opposite O, or north point (see page 173), and when so fixed, we must be able to see through

the upright sights a lamp light in the centre of the pit. After this, you move round the sights, to look at another object at, say, 200 yards distance, in the direction of the workings, being very cautious not to move the theodolite plate in moving round the sights to the object.

Son: Suppose I find the degree opposite the sights is 25. Is not that, then, at an angle of 25 degrees *from* the last sight?—Father: It is so. Now you take up the theodolite, and again fix it at the end of the 200 yards mark, looking back at this 100 yards mark, being able to see a light through the upright sights, when such sights are opposite O, or the north point on the theodolite plate. Then when the theodolite is fixed properly, and you are able to see the mark, you will have to move the sights round again, to see another object in the workings, at, say 300 yards distance.

Son: The degree opposite the sights, from this place to the 300 yards mark, is, I find, 15 degrees, or is it not at any angle of 15 degrees from the previous sight?—Father: Just so. You take up the theodolite again, and fix it at the 300 yards mark, looking back also again to this 200 yards mark, being able to see it through the sights when such sights are opposite O, or the north point on the theodolite plate.

Son: I see, when so fixed, the upright sights are removed round again to look through at another object into the workings. —Father: So they are. Say the next sight is at 400 yards distance, and also at an angle from this sight of 5 degrees. And so you continue in like manner, from sight to sight, taking the angles which vary from previous sights, until the whole mine is surveyed. My object is to give you the principle of the thing, and not to bewilder you with minutes, seconds, and thirds.

EXAMPLE.

The tramgate from pit to working face.

The fourth sight, 400 yards in length, at an angle of 5 degrees from the third sight, or 45 degrees from due north.

The third sight, 300 yards in length, at an angle of 15 degrees from the second sight, or 40 degrees from due north.

The second sight, 200 yards in length, at an angle of 25 degrees from due north.

The first sight, 100 yards in length, due north.

Son: As you have shown *one way* of mine surveying, with the theodolite, which I now well understand, I shall be glad to be informed *how* the other is accomplished.—Father: Well, the first and second sights are taken just in the same manner as the two first sights were by the other mode. The first sight, you know, from the pit was due north, and the second sight was at angle of 25 degrees, looking at an object in the workings 200 yards distance. All that is required then, is to fix the theodolite at the 200 yards mark, and look back (as before) to the 100 yards mark, and in looking back through the sights, you do not require the sights to be opposite O, or the north point on the theodolite plate, but you require the sights to be opposite degree 25. When you have got the degree properly, with the sights opposite 25, then you move round the sights to look through at the other mark at 300 yards distance. After so doing, you will find the sights opposite degree 40,—the direction of that sight being 40 degrees away from the north point. Then you again remove the theodolite to the 300 yards mark, and look back also again to this mark, and in so looking back the sights must be *opposite* degree 40—the same being the degree of the road; and also, when found, it is the guide by which you know or find the degree of the next sight.

Son: After the theodolite is so fixed, are not then the sights removed round so that you may see the next object?—Father: So they are. The object is 400 yards, you know, from this one.

Son: I find the object at the 400 yards mark from here, the sights are opposite the degree 45.—Father: I believe such is the case. Do you not remember the sight, when taken the other way, was at an angle of 5 degrees. What makes it now 45 degrees is, because the 5 is added to the other 40 before;

therefore, it is 45 degrees away round from the north point, or away from due north 45 degrees, that is—$25 \times 25 = 40 \times 5 = 45$. (See page 173 for example.)

Son: Then, if I fixed the theodolite again, and looked back, the sights would have to be opposite degree 45; after which I look forward to another sight, to see in what direction the road varies from the last one.—Father: Just so; and so in like manner you take *back sights* alternately, taking sight after sight, until all is finished. By this mode of surveying, you lay the working on plan just the same as if surveyed with the dial.

How to find the degree of any Tramgate or road in a mine intended to be driven.

Son: I wish to drive a road from the pit to a certain place or object, how, father, must I find the degree to that object?—Father: Make a line on your plan from the point you wish to commence at, to the object intended to drive to; then carry the line parallel to the meridian line; when so done, lay your protracter on the meridian line, after which count round from the north of the protracter until the parallel line of the intended road crosses it, and at such place where the line crosses the protracter, it is the degree of the intended road you require.

Son: Then, father, when I have carried the line of the intended road parallel to the meridian line, and laid down the protracter, if I find the line of the road crosses the protracter at, say 250 degrees, then I shall have to fix the sight of the road with the dial at 250 degrees?—Father: Just so. That is the way.

Miscellaneous Questions.

Son: I have a few miscellaneous questions to ask, which no doubt, you will try to answer.—Father: What are they?

Son: I wish to know how you find the area of, and the number of cubic feet in a circular pit, or in a circular air-gate?—Father: I do it in the following manner:—Measure across the pit or circle, and multiply the distance or diameter by itself; multiply again by 7854, and then strike off the four last figures of the result in the manner below described. Find the area and also the cubic contents of a pit 12 feet in diameter and 365 feet deep.

To find the area and contents of a circular pit or air gate.

The diameter of pit	12	
Multiplied by itself	12	
	144	
Again Multiply by	·7854	Thus the area you see, is 113 feet and very near one tenth of a foot.
	576	
	720	
	1152	
	1008	
Area of pit	113,0976	Also the cubic contents are 41,280 feet, and 6-10th of a foot, the pit being 12 feet in diameter and 365 feet deep.
Multiplied by depth of pit	365	
	5654880	
	6785856	
	3392928	
Cubic contents	41,280,6240	

Son: I may find the cubic feet, then, of any circular pit, or circular air passage, by this mode, be it less or more?—Father: Yes, you will have to adopt this mode of measurement, whether the diameter be in inches, feet, or in yards. If the diameter of the pit had been 12 inches, and the depth 365 inches, the result

would have been the same in inches or in yards, as the case may be. To find the cubic contents of an air-passage not circular, multiply the length of it by the area. Thus the length of the passage may be, say sixty feet, by five feet wide and four feet high. $60 \times 5 = 300 \times 4 = 1200$.

According to the late Dr. Glover, 666 cubic feet of air will sustain a healthy man for twenty-four hours: if so, an air-passage of 1,200 feet would sustain a man, if full of pure air, forty-three hours. One man inhales 135 gallons of air every hour; a pony 540 gallons; a horse 1080 gallons.

Son: I wish to know, father, the rule by which to find the area and cubic feet also, in the sinking of a pit, whatsoever the diameter and depth may be.—Father: The rule to find it is in the books on mensuration. My intention is to show it you, that you may find the area, cubic feet, and also the number of bricks required to wall a pit.

Son: Such information, father, will be very valuable. It will show how to calculate the amount of labour in sinking a pit of say 13 feet diameter, or whatsoever diameter it may be.

To find the area and cubic feet of a pit 13 *feet diameter.*

Diameter 13 feet, multiplied by 13=169, multiply again by ·7854=132·7326, multiply now by 1521, the supposed depth of pit=201886·2846, total number of cubic feet.—Father: You see the rule in the table, how to find the area of a pit, and the cubic feet also. Multiply (as you see) the diameter by itself. Again, multiply 169 by ·7854, and strike off the four last figures, the remainder (132) being the area of pit mouth.

Son: Why strike off the four last figures? Do such figures count for nothing?—Father: The figures you strike off are

decimals. When the highest of them amount to ten, one more is added to the result. Seven is the highest, you see; therefore, it is seven-tenths of a foot, or a little more.

Son: How are the cubic feet of a circular pit formed?—Father: Just in the same manner as you see in the table. Multiply the area of a pit mouth by the depth of it; and again strike off the decimals (see, four there are); and the remainder is the result in cubic feet (201,886).

Son: Is the number of decimals always four, or are they more and less in number?—Father: No; the number of decimals varies; but, whatsoever the number may be, you count and strike them all off.

Son: Give me the rules, now, how to find the circumference of a pit (say 13 feet diameter), and the number of bricks required to wall one.—Father: The following rule in mensuration will enable you to find the circumference of anything circular, whatsoever the diameter may be.

Multiply.........	3·1416
By, say a 13 feet diameter pit......	13
	9·4248
	31·416
	40·8408

Thus, you see the result as seen in the table.

Son: There are, I see, four decimals also in this.—Father: Yes: four is the only number,—circumference of pit 40 feet, you see, and 8-10ths of a foot.

Son: How do I find the area then, father, in feet to be walled?—Father: By multiplying the figures which show the circumference, by the depth of pit to be walled. Supposed depth

521+40,8408=21,278·0568 area to be walled. Again the number of bricks in a foot =5·333+21,278·0568,=113475·8769144. This gives the total number of bricks in the walling of a pit at the supposed depth.

Son: Are there not, father, three more decimals added to the others, which make seven?—Father: Yes; 333 are decimals, which are equivalent to one-third of a brick. If a brick is nine inches in length, and three inches in depth, it will require five bricks and a third to wall one foot area.

Son: I am glad for the information. I think I am able to find the cubic feet, &c., of a pit.—Father: Here are a few tables for your information, in which you may practice.

To find the area and cubic contents of a pit 13 feet 3 inches diameter. Diameter, 13·25 feet by 13·25=175·5625. Multiply again by 7854=137·88678750. Multiply by 3212, supposed depth of pit,=442892·36145000, the total number of cubic feet in shaft.

We will find the circumference of a 13 feet 3 inches diameter pit, and the number of bricks required to wall one of the same diameter. Multiply 3·1416 by the diameter, 13·25, to find the circumference of pit =41·626200 feet. Multiply 41·626200 by 1212, the supposed depth of pit, =50450·954400 feet, area to wall. Multiply 50450·954400 by 5·333, the number of bricks per square foot, =269054·939815200, the total number of bricks required.

Now we will find the area and cubic contents of a pit 13 feet 6 inches in diameter. Multiply the diameter, 13·5 feet by 13·5 feet =182·25, the sum of diameter multiplied by itself. Multiply 182·25 by ·7854=143·139150 feet area of pit mouth. Multiply 143·139150 by the supposed depth of pit 2315=331367·132250, total number of cubic feet.

Find now the circumference of a 13 feet 6 inches diameter pit, and number of bricks required to wall one of the same diameter. Multiply 3·1416 by the diameter, 13·5=424·1160 feet circumference of pit. Multiply 42·41160 by the supposed depth of pit, 1232=52251·09120 feet area to wall. Multiply 52251·09120 by number of bricks per square foot, 5·333=278655·06936960, total number of bricks required.

We must now find the area and cubic contents of a pit 13 feet 9 inches diameter. Diameter, 13·75 by 13·75=189·0625 feet, sum of diameter, multiplied by itself. Multiply 189·0625 by ·7854=148·48968750 feet, area of pit mouth. Multiply 148·48968750 by supposed depth of pit, 3322=493282·74187500, total number of cubic feet.

Also find the circumference of a 13 feet 9 inches diameter pit, and the number of bricks required to wall one of the same diameter. Multiply 3·1416 by the diameter, 13·75=43·197000 feet. Multiply 43·197000 by supposed depth of pit, 3322= 143500·434000 feet, area to wall. Multiply 143500·434000 by number of bricks per square foot, 5·333=765287·814522000, total number of bricks required.

Son: Any person able to add a few figures together, may, I think, father, understand the tables.—Father: My object, you know, is to make you understand all I say.

Son: Have you any knowledge, father, of what power is produced when a quantity of gas is ignited? that is, do you know what gas is capable (in proportion to its quantity) of propelling before it?—Father: I know the power of gas, when ignited, is very great, as may be seen often in mines after explosions. At the Hetton colliery explosion, December 20, 1860, it was supposed that the explosion had been caused by a flue, containing

about 7,000 cubic feet, becoming filled with gas, which afterwards ignited. The scientifie and chemical evidence given by Mr. Isaac Lowthian Bell, and Dr. Thomas Richardson, was this:—Supposing the 7,000 feet to be exploded, it would become 56,000 feet, which would immediately be coverted into after-damp. The temperature of these exploded gases being about 1,500 degrees Fahrenheit, or a bright red heat, the power would be equal to 75 quarter casks of gunpowder, of 25lbs. each; that is, an explosion of 1,875lbs. of gunpowder. So you may judge by this the power of an explosion.

Son: Is blasting coal with powder allowed in mines where safety-lamps are used?—Father: It is allowed in some mines.

Son: Those who allow blasting know well, I presume, that explosive gas (carburetted hydrogen) cannot ignite at the flash of powder?—Father: Touch paper is used for lighting with.

Son: Touch paper is used. That is not, father, the question. Will not explosive gas ignite at the flash of powder, where blasting is allowed?—Father: If explosive gas ignites at either a naked light or safety-lamp, so also will it ignite at the flash of powder.

Son: You know it will, then?—Father: To be sure; and persons who think otherwise I envy not their knowledge.

Son: Do not people say explosive gas cannot be destroyed?—Father: Yes; but it is well known to many, that gas in a stocked place has often exploded in the safety-lamp, and after the place has been filled with tobacco smoke, naked lights have been used shortly after with safety; and, if the quantum of gas be above the explosive mixture, the gas will extinguish the tobacco in the pipe.

Son: Suppose much wind passes around the place where a

miner is working, is he to know by this that his place is safe from explosions?—Father: No; unless his knowledge is such as enables him to know the purity of the wind; as the safety of his place is not in proportion to the quantity of wind, but in proportion to the purity of of it.

Son: If the same quantity of wind passes around his place every day, is he to know by this that his place is safe from explosions?—Father: No; his place may not be safe then, because a change of the weather will cause a larger accumulation of gas at one time than at another; and if a larger quantity of gas accumulates, the wind will be more impure at one time than at another.

Son: But suppose the miner can only see a little gas in the air which passes around his place; can he then know it to be safe?—Father: No; he cannot then say his place is safe, unless he has a knowledge of the several degrees of the impurity of the wind; because, if gas be pure, very little will be seen before it explodes; therefore, he should have a knowledge of the quality as well as the quantity of the gas, to have a proper knowledge of the safety of his place.

Son: Suppose you had two pits, father, one say of 126 feet area, and the other of only 100 feet area, which of the two, the larger or the smaller, would you make into an up-cast?—Father: The larger one would make the best up-cast, because the air expands on account of the heat of the furnace, and the high temperature of the mine, in passing through the workings to the up-cast; and also from gases being added in the air from the strata, space would be required in the shaft for such expansion, otherwise, the velocity of the air in the up-cast would be greater than in the down-cast; and if the velocity be greater, the friction

would be greater; the said quantum of air cannot ascend up the shaft as it would do if the shaft were larger in proportion to the expansion of the air, because, the friction would impede the ascent of the air, as a weight to a balloon would impede its ascent: for air is not propelled upwards out of a mine, but ascends like a balloon of itself—the ascent of the said air being in proportion to its diminished lightness caused by its expansion.

Son: How much do you say air expands by heat?—Father: 480 parts of air expand and become 481 parts at 33 degrees of heat, and increase one part for every additional degree—so that when the volume of air becomes increased to 600 parts, the temperature is then at 152 degrees. Therefore, suppose the down-cast air at a temperature of 32 degrees, and the up-cast air at a temperature of 152 degrees—the volume of air in the up-cast would have become expanded to 1-5th larger than the down-cast air; and if 1-5th expanded it would be 1-5th less in weight, in the space first occupied.

Son: Suppose the coal in the workings should dip or rise, would the furnace produce the same quantum of air, if the up-cast shaft was fixed in one part of the royalty as in another? —Father: The same power of a furnace would produce more air if the up-cast was fixed in an elevated position: because, as before stated, the air expands in passing through the workings; and this being the case, its tendency is to ascend and not descend. It therefore follows that if a furnace be fixed where the shaft is in an elevated position, so that the air in passing through the workings may ascend and not descend, it will produce a larger quantity of air than one of the same power which is not fixed in such a position; because in a furnace so fixed, the air

will assist the furnace, as it ascends through the mine to the up-cast, but will not do so if it be caused to descend in passing to the up-cast. You may cause air to descend against the nature of what it would do, like two horses pulling against each other; the strong one would pull away the other; so, in like manner, a larger furnace would be required than needful.

Son: Do you know, father, what quantity of air is produced in mines per minute?—Father: The quantity produced is not alike at all mines, in some more and others less. The following will give you a knowledge of what has been produced in some mines.

DURHAM	Hetton Colliery		190,000	cubic ft.	per min.
NORTHUMBERLAND	Wallsend	do.	120,000	"	"
YORKSHIRE	Ardsley Main	Colliery	80,000	"	"
"	Lund-hill	do.	50,000	"	"
DERBYSHIRE	Speedwell	do.	40,000	"	"
*LANCASHIRE	Sutton Heath	do.	80,000	"	"

Son: Is not the quantity of air which rushes through and around the workings of a mine measured by the anemometer? Father: Yes, it is one way of measuring it.

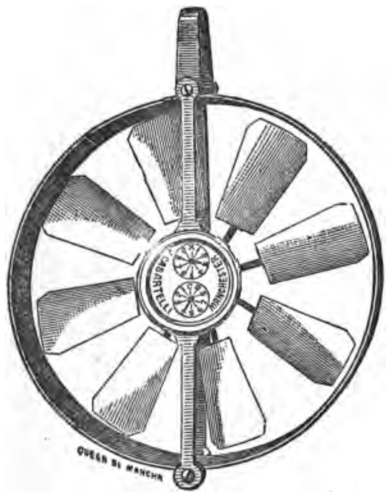
Son: Have you seen the anemometer?—Father: Yes; It was invented by Mr. Biram, and manufactured by Mr. John Davis, Optician, Derby; and also by Casartelli, of Manchester.

Son: How is a person, father, to ascertain by the anemometer the number of cubic feet of air which rush through the air passage?—Father: In the following manner. The registering apparatus is in front of the wheel, and consists of six small circles marked respectively X, C, M, XM, CM, and M, the divisions on which denote units of the denominations of the

*This quantity of air was produced by one furnace 4 feet by 6 feet, and one up-cast of 9 feet diameter.

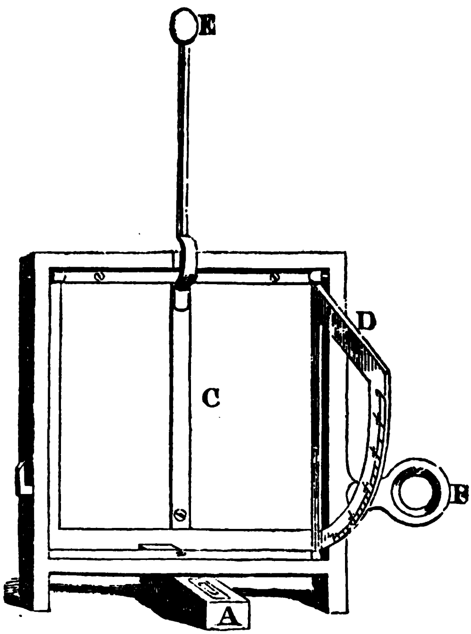
respective circles; in other words, the X index in one revolution passes over its ten divisions, and registers (10 × 10) or 100 feet: the C index, in the same way, 1,000 feet; and so on, up to 10 million feet; so that an observer has only to record the position of the several indices, at the first observation (by writing the lowest of the two figures on the respective circles between which the index points in their proper order), and deduct the amount from their position at their second observation, to ascertain the velocity of the air which has passed during the interval; this multiplied by the area in feet of the passage where the instrument is placed, will show the number of cubic feet which have passed during the same period. These anemometers have been much improved recently by Mr. Casartelli, of Manchester, and are made by him.

Casartelli's improved Biram's Anemometer.



Son: Suppose I fix the anemometer further in the air-gate, and the number of revolutions be, say 1,000 feet; all I have to do, then, is to multiply the area of the passage by the 1,000 feet? —Father: Just so. Suppose the area of the air-gate be 16 feet; multiply 16 by 1,000, and the result will show 16,000 cubic feet of air, which has passed in the space of time you have had it fixed—may be in a minute.

Casartelli's Dickinson's Anemometer.



DIRECTIONS FOR USE.

1.—Turn the Level A at the bottom to a right angle to its present position. 2.—Turn the small Circular Handle B to the outside. 3.—Raise the Fan C to a horizontal position; then pass the Quadrant D under the Fan until it is at a right angle to it. 4.—Insert the Balance Weight E at the top of the Fan. 5.—Place the Instrument perpendicular by the Level. The figure on the Quadrant to which the Fan is raised, shows the velocity in feet per minute: the velocity thus ascertained, multiplied by the area, gives the amount of ventilation in cubic feet per minute.

Father: This anemometer was suggested by Joseph Dickinson, Esq., inspector of mines, arranged and made by Mr. Casartelli, of Manchester. It is very convenient, and much used by underlookers and deputies. No time for starting and stopping it is required, only to note the velocity or speed of the current, which is marked on the quadrant.

Son: Nos. 200, 300, 700, &c., I see on the anemometer. If the force of the air current should send the fan to 700, this would show the velocity of the current to be travelling 700 feet per minute?—Father: Just so, and that velocity multiplied by the area of the passage would give the quantity of air per minute. Sometimes the current will be intermittent, and the fan will move between two figures or divisions; in this case take the mean between the two figures as the velocity indicated. For example,—suppose the fan moves between 300 and 400, the velocity will be 350 feet per minute.

Son: Is there any other kind of anemometer?—Father: Yes, here is another by Mr. Casartelli, 43, Market-street, Manchester. (See next page.)

This anemometer (says Mr. Casartelli) is much recommended for its portability and great accuracy. Owing to the lightness of its construction, the error due to friction is reduced to a minimum.

In using the anemometer, it may be placed on a stand, held in the hand by the bottom, or on a rod fitting in the socket which accompanies the instrument, and which screws into the bottom of it. The Fan always to *face* the current.

The instrument is made with *two* or more circles; the outer circle with the long pointer, represents *units*, the others are *hundreds*, *thousands*, *tens of thousands*, *hundreds of thousands*, *and millions*. Each circle is figured 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, which mean one, two, or three hundreds, or thousands, &c., according to the circle. Suppose the unit or long hand pointed to 40, that of the hundred circle to 3, of the thousand circle to 7, of the tens of thousands to 9, of the hundreds of thousands to 6, and of the millions to 4, the reading would be 4,697,340.

In taking a measurement, blow the fan until the large hand points to 0, then put down the *present* reading of the various circles, and after it has run one minute or other length of time, you take a second reading. Substract the *first* from the *second* reading, the difference will be the

velocity per minute, or per hour, or per day, according to the length of the running.

In order to *start* to time and *stop* to time, there is a *stop* on one side of the rim outside of the face of the instrument which can be put off (say at 60) by the minute hand of the watch, and put on at the end of the minute so as to get the exact running in the minute without stopping the Fan.

Always be careful not to bend the fan or injure it, as it is so light.

Son: I thank you for the information, father, on mines. I had no idea our conversation would have continued so long, yet I am glad that it has done so, as I have now more information than I had before, for which I am thankful.—Father: My object in my life is to do all the good I can. I take a pleasure in doing so—in putting, if possible, the right man in the right place; in helping those who cannot help themselves; and in giving knowledge to those who require it. You have got now a knowledge of gases; how mines generate gases; why one mine discharges more gas than another; the cause of some mines discharging a mixture of gases; how it is that a change in the weather affects the workings of a mine; the power of an explosion of fire-damp, and how to diminish the power and cause; why air is propelled down and around the workings of a mine; several modes of ventilation; the danger of one road and the safety of another; the friction of the air in mines; the great friction produced by one mode of ventilation, and how it may be reduced by another; several ways by which friction is produced; the power of the furnace, and the quantity of air produced by an increased power; several modes by which coal is worked out in mines; why so many ways are adopted; and also of who are the best and most competent persons to manage the underground

workings of mines; the mode of dialling, and also laying the workings on a plan. I must now, my son, draw to a close. I hope what I have said you will inwardly digest, so that my labour bestowed upon you will not be in vain. If I have been successful, I shall be well rewarded, my object being only to give you information. I would beg of you, if ever you have charge of the underground workings of mines, to do that which is right, as far as is in your power, both to the employer and the employed. Give to every person his right and due. Do not give away your master's money, unless you have labour equivalent for it, as his money is not yours. Neither give away the workmen's labour to the master, for by so doing you rob them of their rights and living. Do to each as you would wish each to do to you. Study to be upright in all your dealings with every person, remembering that life will only be of short duration, so that you may be found right for the life to come.

Son: It is your will, I know, father, for me to do what is right and just, and I hope it will always be my endeavour to do so; if not, I may expect to be beaten with many stripes.—Father: If all people go astray, you are not justified in doing wrong. Never take advantage of a person because his profession of religion be not the same as yours; if he is sincere in his worship, look upon him as a friend and brother.

QUESTIONS AND ANSWERS

WRITTEN TO ASSIST

APPLICANTS FOR CERTIFICATES

FOR APPOINTMENTS TO THE

MANAGEMENT OF COLLIERIES.

Examiners: We presume you to be a steady, sober, and attentive person.—Applicant: I have not had for years any intoxicating drinks, nor ever been drunk.

Examiners: Can you show any proof of your sobriety and attentiveness?—Applicant: I have a note here from my employer, with whom I have served for years, one from the manager of the colliery, and another from our minister; and I have also a temperance certificate.

Examiners: You have had a situation, no doubt, in mines?—Applicant: I have worked my way up from a fireman to a deputy, and from a deputy to an under-viewer or under-looker.

Examiners: Then you are a thorough practical man?—Applicant: My experience in mines began in early life.

Examiners: Have you received a mathematical education?—Applicant: A little; but in mathematical knowledge I am self-taught.

Examiners: You have some knowledge, we presume, of decimals and fractions.—Applicant: Yes. My information of

figures will enable me to measure, I think, anything required in the management of mines.

Examiners: You will be glad to give us, no doubt, a proof of your knowledge?—Applicant: I will give you a few measurements with which near all things in mines and collieries may be measured, or the contents obtained; such as pit boxes, waggons, air-ways, currents of air, timber, coal, circular-measurements, or other cubical contents. Here they are:—

The following will give you a knowledge how to find the area of any air passage.

ft.	in.	
7	9	
3	6	
21	0	
2	3	
3	6	
	4	6
27	1	6

ft.	in.	
9	8	
7	6	
63	0	
4	8	
4	6	
	4	0
72	6	0

Another a little more difficult.

ft.	in.	p.		
240	10	8		
9	4	6		
2160	0			
7	6			
	6	0		
80	0			
	3	4		
		2	8	
10	0	0		
		5	0	
			4	0
2258	4	0	0	0

To find the following area will yet be a little more difficult.

ft.	in.	p.		
7	5	9		
3	5	3		
21	0			
1	3			
	2			
2	11			
	2	1		
		3	9	
	1	9		
		1	3	
			2	3
25	8	6	2	3

ft.	in.	p.		
368	7	5		
137	8	4		
2576	0			
11040	0			
36800	0			
79	11			
4	9	1		
245	4			
	4	8		
		3	4	
10	2	8		
		2	4	
			1	8
50756	7	10	9	8

The cubical contents of a coal waggon, a box, or any cubical measurement.

ft.	in.	p.		
1	7	6		
1	1	6		
1	0			
	7	0		
		6	0	
	1	0		
		7	0	
			6	0
		6	0	
		3	6	
			3	0
1	9	11	3	0
20	6			
20	0			
15	0			
1	6	4		
		5	0	
	6	0		
	4	6		
		5	6	
			1	6
37	5	8	7	6

The cubical contents of another.

ft.	in.	p.		
1	2	9		
1	2	9		
1	0			
	2	0		
		9	0	
	2	0		
		4	0	
		1	6	
		9	0	
		1	6	
			6	9
1	6	1	6	9
19	0	0	0	0
19	0			
9	6			
	1	7		
		9	6	
		1	2	3
28	8	5	8	3

ft.	in.			
16	9			
6	6			
96	0			
4	6			
8	0			
	4	6		
108	10	6		
8	4	6		
864	0			
6	8			
	4	0		
36	0			
	3	4		
		2	0	
4	6	0		
		5	0	
			3	0
911	9	11	3	0

Another, a little more difficult.

97	5			
18	3			
776	0			
970	0			
7	6			
24	3			
	1	3		
1777	10	3		
2	3			
3554	0			
1	8			
		6	0	
444	3			
	2	6		
			9	0
4000	2	0	9	0

The cubical contents of a Coal Box, length 2 feet 5½ inches, by 2 feet 7¼ inches, depth 2 feet 4¾ inches.

ft.	in.	p				
2	5	6				
2	7	3				
4	0					
	10	0				
	1	0				
1	2					
	2	11				
	0	3	6			
	0	6	0			
	0	1	3			
		0	1	6		
6	4	9	10	6		
2	4	9				
12	0					
	8	0				
	1	6				
		1	8			
			1	0		
2	0					
	1	4				
		3	0			
			3	4		
				2	0	
	4	9				
		3	0			
			6	9		
				7	6	
					4	6
15	4	3	7	10	10	6

ft.	in.	p.
0	8	0
0	8	0
0	5	4
10	0	0
4	2	
	3	4
4	5	4

To find the area of a pit 13 feet diameter:

13	Diameter multiplied by 13.
13	
39	
13	
169	
·7854	
676	
845	
1352	
1183	132 feet area, ·7326 being decimals, near 132¾ feet area.
132˙7326	

To find circumference of a 13 feet pit:

3·1416
13
94248
31416
40·8408

Circumference 40¾ feet. See also pages 176 to 180 for more decimal measurements.

Examiners : The measurements are useful for colliery work; you are able, we presume, to survey with a dial the workings of a mine?—Applicant: Yes, and survey mines also with the theodolite, and lay the workings on plan.

Examiners: Then you can survey land, no doubt?—Applicant: I am able to do land surveying; but, you know, I am self-taught, not having served in a surveyor's office.

Examiners: We require you to produce a plan of the workings of a mine surveyed and planned by you, and another on land surveying; or, we require some proof that you are able to survey, &c.—Applicant: I have here a number of plans; they

may not look so well finished as they might had I served my time with a surveyor, but I know them to be correct.

Examiners: Have you a perfect and thorough knowledge of mine gases?—Applicant: I think so.

Examiners: What do you know of mine gases? —Applicant: The atmosphere, I know, is a compound, or a mechanical mixture, in 100 parts, it consists of 21 of oxygen, and 79 parts of nitrogen, or 1 part oxygen and 4 parts nitrogen. Oxygen gas is a supporter of combustion, and if left to exert its native energies, it would melt the hardest substances, and set the earth in flames; everything would blaze with a rapidity which would carry destruction through the whole expanse of nature; oxygen would feed the flames on every side, and set at defiance the united efforts of every engine in the fire brigade. It is not so with nitrogen, the other ingredient of the atmosphere. If the air consisted of nitrogen only, every species of fire and flame would be extinguished, and all the tribes of animated nature instantly destroyed. Nitrogen, then, is not a supporter of combustion, but it is made in order to temper down or dilute the excessive strength of the oxygen.

Examiners: You have a knowledge, no doubt, of the composition of fire-damp?—Applicant: I think so. It is a compound, and consists of two gases, hydrogen and carbon; in say five feet of fire damp, four of it consists of hydrogen, and one carbon. Hydrogen is combustible only in oxygen or air, but does not itself support combustion. Carbon is the chief constituent of coal, and is an ingredient in the composition of animals and plants.

Examiners: Do you know what after-damp consists of?—Applicant: Yes. It is composed of three gases or ingredients.

Examiners: What are they?—Applicant: In 11 parts of after-damp, 1 part consists of carbonic acid gas, 2 parts of watery vapour, and 8 parts of nitrogen. Carbonic acid gas, or black-damp, is a positive poison, nitrogen merely poisons by excluding oxygen, that is to say, carbonic acid lays violent hands upon its victim, and kills him at once, while nitrogen starves him to death by excluding all nourishment, therefore it is death to all who breathe it.

Examiners: From only a few gases, then, nearly all other gases are, when mixed, obtained?—Applicant: Yes. Air, water, explosive gas, after-damp, carbonic acid gas are obtained from only four gases.

Examiners: Which four gases are they?—Applicant: The following.

	Symbol		Atomic Weight.
Hydrogen............	H	....	1
Oxygen...............	O	....	16
Nitrogen	N	....	14
Carbon	C	....	12

Examiners: We presume you know the weight or specific gravity of mine gases?—Applicant: The specific gravity of the atmosphere is 1·000, fire damp 0·555, and carbonic acid or black damp is 1·524.

Examiners: Do the variations in the weight of such gases affect mines, or are mines affected by the weight of them?—Applicant: Yes, mines are affected in the following manner: fire-damp being only 0·555, is but, or little more than, half the weight of the atmosphere 1·000, and as such is the case, fire-damp makes it way up into every hole in the roof, and in all workings which are very high, to the top of which it rises:

and to bring the said gas down from those high places, both a propelling force in the current and a large quantity of it also is required.

Examiners: Does black-damp, by its great weight, also affect mines?—Applicant: Black-damp, or carbonic acid gas, being 1·524, is one-third heavier than the atmosphere 1·000, and near two-thirds heavier than fire-damp 0·555, and as such is the case it settles down to the floor, like mud in water, and fills the lowest workings, and to bring black-damp up and away therefrom a strong propelling force in the ventilating current is required, for if the propelling force in the current is insufficient, the air will pass through the gas and not bring it away.

Examiners: How are mine gases discharged or produced?—Applicant: Just in the same manner as steam is discharged from a boiler much compressed, when the weight on the valve is insufficient to keep it in. The strata in mines is pressed with gases to overflowing; and when gas discharges therefrom it is when, and at the time the atmospheric weight is insufficient to keep it in.

Examiners: How is it that a mine may give off to-day a certain quantity of gas, and a large increase take place to-morrow?—Applicant: That is owing to the change in the atmospheric weight, which changes from one day to another. Just in like manner if the weight on a boiler valve be reduced just at the time it is blowing off, an increase in the quantity of steam will take place, and so an increase in the quantity of gas will take place, when and at the same time the atmospheric weight is reduced.

Examiners: But every mine does not give off alike the same quantity of gas, when and at the same time the atmospheric

weight is reduced; yet this weight of the atmosphere is reduced from all mines alike, and at the same time too. How is that?—Applicant: I know mines do not give off all alike the same quantity of gas, and yet the atmospheric weight is reduced at the same time alike from all, that is owing to the variation in the compression of gas in the strata, caused by the length of time some mines have been discharging gas longer than in others; in like manner one boiler is less compressed with steam than others, because of its being blowing off longer.

Examiners: But when mines are first opened out, they do not all give off alike the same quantity of gas, some may discharge a large quantity, others little or no gas. How is that?—Applicant: The strata from the bottom to the surface is more open in some mines than in others, and where the strata is open, gas escapes to the surface, and never able to accumulate in the mine or strata, therefore when the mine was opened no gas or little of it was found, while in others with no open strata a large quantity was found.

Examiners: Do you know how a motion of the current is caused to move along and through the workings of a mine?—Applicant: I think so. Its motion is caused by propulsion or exhaustion at one shaft or at the other, therefore, whether by propulsion or exhaustion, a great moving propelling power in the current is produced at the down-cast over that at the up-cast; the least minimum density and weight of the air is always at the up-cast, so that from the first yard at the up-cast, the air becomes more and more dense, and the propelling moving force increases step by step, every yard in the air way along its route from stage to stage this propelling force increases until the greatest maximum density and propelling moving weight is obtained at

the down-cast, and this motion is the current produced. See pages 50 to 62 on ventilating powers or the current's motion.

Examiners : What mode of ventilation would you adopt in mines discharging explosive gas?—Applicant: The mode of separate divisions, so that I would divide, split, or separate the air into distinct currents or parts of say 4,000 cubic feet of pure air per minute for each separate division.

Examiners: Why would you make divisions?—Applicant: Because by so doing I should prevent explosive gas from collecting into large quantities, as the danger lies in the gathering and exploding of too large a quantity of gas.

Examiners: Then because of that you think it more safe to have divisions?—Applicant: Just so, because if 100 feet of gas were discharged per minute in the workings of one division, 500 feet of gas might be discharged in the workings of 5 divisions, and to ventilate all with one current the whole volume of 500 feet of gas would be exploded at once, but only 1-5th of it if ventilated separately, and so the power of the explosion would be reduced to 1-5th, the quantity of choke-damp left after the explosion would be reduced to 1-5th, the danger to life would be reduced to 1-5th; and the quantity of air obtained by splitting much increased, because the friction of the current would be much decreased.

(See pages 79, 119, 127, 129, 131, for plans.)

Examiners: You know then what is meant by friction in the air-current?—Applicant: It is a rubbing of the current along the roof, floor, and sides, in its passage through the mine.

Examiners: What steps would you take to reduce its friction? —Applicant: I would shorten its route by making divisions or enlarging the passage through which it had to pass. (See p. 101.)

Examiners : What plan would you adopt in the working out of coal ?—Applicant: In every mine the best possible to suit the nature of the roof, floor, &c.

Examiners : Could you not adopt a plan suitable for all mines ? —Applicant: Impossible, except there were no change in the roof, floor, &c.; if so, then one plan of working out coal would do for every mine, but as it is not so, I must first obtain a knowledge of the nature of the roof, &c., to enable me to adopt a plan suitable for the mine intended to work coal out.

Examiners: We presume you know several ways then of working coal?—Applicant: I have a knowledge of pillar working, bank or wide work, drifts, and long wall work, &c., &c.

(See page 115 on working coal plans.)

Examiner: Have you superintended the sinking of pits or shafts?—Applicant: I have had a little of that, having had to measure shafts during sinking, and being present when putting in rings, water tables, and walling of shafts, &c.

Examiners: Have you had anything to do with engines, boilers, and furnaces, both above and below ground?—Applicant: I have a knowledge of such, yet not superintended the erection of the same.

Examiners: Can you calculate the nominal horse power of a steam engine?—Applicant: I think so.

Examiners: We will suppose then, the diameter of the cylinder to be 55 inches, travelling 200 feet per minute, and 7 lbs. pressure on the piston, let us know its nominal horse power? —Applicant: I will calculate the same in the following manner:

```
                         55  Diameter multiplied by
                         55
                         --
                        275
                       275
                       ----
                       3025
                      .7854
                      -----
                      12100
                     15125
                    24200
                   21175
                  ---------
                  2375·8350   Square inches in the cylinder.
                        220  ´Speed of the piston.
                  ----------
                  475167000
                 47516700
                ------------
               522683·7000
                         7   Average pressure on piston.
               ------------
Divided by 33000)3658785·9000(110 horse power.
                 33000
                 -----
                  3587
                 33000
                 ------
                  28785  Remainder.
```

Examiners: We will speed the engine to 360 feet per minute, and an average pressure on the piston of 20 lbs. per sq. inch above the pressure of the atmosphere, let us know its nominal horse power ?—Applicant: I will do so.

```
          2375·8350   Square inches in cylinder.
                360   Speed of the piston.
         ----------
         1425501000
         71275050
         ----------
         8553006000
                 20   Average pressure on piston.
         ----------
       7106012·0000—Carried forward
```

Divided by 33000)17106012·0000(518 horse power.
165000

60601
33000

276012
264000

12012 Remainder.

Examiners: Can you give the quantity of water a pump will lift, 12 inches diameter, 66 inches stroke, and 27 strokes per minute?—Applicant: I will try to give the quantity.

12 Diameter multiply by
12

144
·7854 Decimal area.
144 Circular inches multiplied by

31416
31416
7854

113·0976 Square inches of pump barrel.
66 Length of stroke.

6785856
6785856

7464·4416 Cubic inches.
27 Strokes per minute.

522510912
149288832

Divided by 277·274)201539·9232(726 gallons.
1940918

744812
554548

1902643
1663644

238·9992 238 inches and ·9992 decimals over.

WEIGHT OF WATER.

1 cubic foot 62·5 lbs.
1 cubic foot 6·25 gallons nearly.
1 gallon 10 lbs.
1·8 cubic feet 1 cwt.
35·84 cubic feet 1 ton.
11·2 gallons 1 cwt.
224 gallons 1 ton.
277·274 cubic inches 1 gallon.

Examiners: Do you understand the science of hydrostatics? —Applicant: I profess to know a little of that science, or the pressure, motion, and force of fluids.

Examiners: Suppose then a cask was filled with liquid, and a long tube inserted tightly into the top, the area of the cask being 2000 inches, and the area of the tube about 1-10th of a square inch, what pressure would be produced by pouring 3 lbs. of water into the tube?—Applicant: I will try to give the amount of the pressure.

```
             10  Area of tube.
              3  Lbs of water.
            ---
             30  Lbs. pressure per sq. inch.
           2000  Area of cask.
          -----
          60000  Lbs. pressure.
1 cwt.=112)60000(535 cwts. 80 lbs.
          560
          ---
          400
          336
          ---
           640
           560
           ---
            80
```

This will show 535 cwts. and 80 lbs. of pressure produced by 3 lbs. of water.

Examiners: Suppose two circular boards form a pair of bellows, a long tube inserted into the top, the area of the board is 144 square inches, the tube half a square inch; pour into the tube 2 lbs. of water (after the bellows have been partly filled with water), what pressure will be produced?—Applicant: The pressure produced from the 2lbs. of water will be 576 lbs.

144	Area of bellows.
4	Lbs. pressure per sq. inch.
576	Lbs. of pressure produced.

The weight and pressure of fluids lead to many strange and important results.

Examiners: Then you have some knowledge, no doubt, of the science of Pneumatics?—Applicant: I also understand a little of this science, such as the mechanical properties of the atmosphere, its resistance, its pressure, its elasticity; and how the air acts on barometers, syphons, syringes, air pumps, water pumps, fire engines, &c., &c.

Examiners: Have you a knowledge of Mechanics?—Applicant: I have some knowledge of the mechanical laws of motion, such as the inclined-plane, the wedge, the screw, the pulleys, the lever, and the balance; so that if power be gained there is, I know, loss in motion. (It would be well for Applicants to study well the above sciences.)

Examiners: Do you know the strength of materials, the breaking strain of chains, hemp ropes, steel and wire ropes, the strength of iron and timber?—Applicant: I have some good tables and rules to show the same.

Examiners: Let us see them.—Applicant: Here they are:—

STRENGTH OF MATERIALS.

*To find the breaking strain of hemp ropes.**

$$\text{Breaking weights in tons} = \frac{\text{circumference squared in inches.}}{4}$$

Examiners: What is the breaking weight of a rope eight inches in circumference?—Applicant: You may find it in the following manner:

$$\frac{8 \times 8}{4} = 16 \text{ tons.}$$

To find the weight which may be safely appended to a hemp rope :—

$$W = \frac{\text{circumference squared in inches.}}{10}$$

Examiners: What weight might be safely appended to a hemp rope ten inches in circumference?—Applicant: Here you have it:

$$\frac{10^2}{10} = 10 \text{ tons. Answer.}$$

COLUMNS.

Table of practical formulæ by which to determine the amount of weight a column of given dimensions will support, in pounds.

For a rectangular column of cast iron.................W= $\dfrac{15300\ l\ b^3}{4\ b^2 + \cdot 18\ b^2}$

For a rectangular column of malleable iron.........W= $\dfrac{17800\ l\ b^3}{4\ b^2 + \cdot 16\ l^2}$

For a rectangular column of oak ....W= $\dfrac{3960\ l\ b^3}{4\ b^2 + \cdot 5\ l^2}$

For a solid cylinder of cast iron ....W= $\dfrac{9562\ d^4}{4\ d^2 + \cdot 18\ l^2}$

For a solid cylinder of malleable iron.................W= $\dfrac{11125\ d^4}{4\ d^2 + \cdot 16\ l^2}$

For a solid cylinder of oak ....W= $\dfrac{2470\ d^4}{4\ d^2 + \cdot 5\ l^2}$

Note.—W = the weight the column will support in lbs.; b = the breadth in inches; l = the length in feet; d = the diameter in inches

* Tables are to be had showing the breaking strain of ropes, &c. If the applicant be in possession of them, the examiners should be satisfied.

To find the ultimate transverse strength of timber.

1.—When the beam is supported at both ends, and loaded in the middle :—

Let L = length in inches.
B = breadth „
D = depth „

$$M = \begin{cases} 1672 \text{ for English oak.} \\ 1556 \text{ for beech.} \\ 1013 \text{ for elm.} \\ 1632 \text{ for pitch pine.} \\ 1341 \text{ for red pine.} \\ 900 \text{ for larch.} \end{cases}$$

$$W = \frac{D^2 \times B \times 4 \times M}{L}$$

$$\text{or } W = \frac{4\ D \times B\ D \times M}{L}$$

Examiners: What weight will it require to break a beam of pitch pine, supported at both ends and loaded in the middle, the breadth being seven inches, depth nine inches, and length thirteen feet?—Applicant: You may find the same thus:

$$\frac{9^2 \times 7 \times 4 \times 1632}{156 \text{ ins.}} = 23727 \text{ lbs.}$$

The above result must be multiplied by three if the load is distributed uniformly along its entire length. It may easily be remembered, what may be learned from the above rule, that the strength of timber varies as the square of the depth multiplied by the breadth. Thus, a plank 11 X 3 laid flatways would bear little more than one-fourth of the weight that it would sustain edgeways. because 3 X 11=99, and 11^2 X 3=363. A plank of pitch pine of these dimensions, and 7ft. in length between the supports, would bear

$$\text{Flatways } \frac{4 \times 3 \times 11 \times 3 \times 1632}{84} = 6693 \text{ lbs.}$$

$$\text{Edgeways } \frac{4 \times 11 \times 3 \times 11 \times 1632}{84} 28210 \text{ lbs.}$$

2.—When the beam is supported at one end and loaded at the other: —

$$\frac{D^2 \times B \times M}{L}$$

Examiners: What weight will break a beam of larch fixed at one end and loaded at the other, the breadth being 5in., depth 7in., and length 5ft. 6in.?—Applicant: Here you have it:

$$\frac{5^2 \times 7 \times 900}{66} = 2386 \text{ lbs.}$$

The beam, if loaded in the middle, will bear half as much more weight, and if loaded uniformly along the entire length, the above result must be doubled.

These rules show how to find the weight that will BREAK the beams —the weight that may be safely placed upon them is not more than one-fourth to one-third.

Examiners: Please give the size, weight, and strength of round and flat ropes.—Applicant: Here you have tables shewing these qualities in flat and round ropes of various materials and sizes.

ROUND Steel Wire Ropes.		ROUND Iron Wire Ropes		ROUND Hemp Ropes of Equivalent Strength			
Circumference	Weight per fm.	Circumference	Weight per fm.	Circumference	Weight per fm.	Working Load	Breaking Strain.
Inches	Lbs.	Inches	Lbs.	Inches	Lbs.	Cwts.	Tons
3½	11	4⅝	18	12	32	108	34
3⅜	9½	4¼	16	11	30	96	29
3⅛	8¼	4	14	10	28	84	25
3	7½	3¾	13	9½	25	78	23
2⅞	7	3⅝	11¾	9	22	70	21
2¾	6	3½	11	8½	20	66	19
2⅝	5¾	3⅜	9½	8	16	57	17
2½	4¾	3⅛	8¼	7½	14	50	15
2⅜	4½	3	7½	7	12	45	14
2¼	4	2⅞	7	6½	10	42	13
2⅛	3¾	2¾	6	6	9	36	11
2	3¼	2⅝	5¾	5½	8	34	10
1⅞	3	2½	4¾	5	7	28	9
		2⅜	4½	4¾	6½	27	8
1¾	2½	2¼	4	4½	6	24	7
		2⅛	3¾	4	5	22	6½
		2	3¼	3¾	4½	20	6
1½	1¾	1⅞	3	3½	4	18	5
1⅜	1½	1¾	2½	3	3½	15	4
1¼	1¼	1½	1¾	2¾	3	10	3
1⅛	1	1⅜	1½	2½	2½	8	2½
⅞	¾	1¼	1¼	2¼	2	6	2
¾	½	1⅛	1	2	1½	4	1½
		⅞	¾	1¾	1	3	1
		¾	½	1½	¾	1½	¾

FLAT Steel Wire		FLAT Iron Wire		FLAT Hemp of Equivalent Strength			
Size in Inches	Weight per fm.	Size in Inches	Weight per fm.	Size in Inches	Weight per fm.	Working Load	Breaking Strain
Inches	Lbs.	Inches	Lbs.	Inches	Lbs.	Cwts.	Tons
3¼ by ⅝	18	4½ by ⅞	30	8½ by 2¼	46	120	46
3 ,, ⅝	16	4¼ ,, 13/16	27	7½ ,, 2⅛	40	108	40
2⅞ ,, 9/16	14	4 ,, ¾	24	7 ,, 1⅞	36	96	36
		3¾ ,, ¾	22	6½ ,, 1⅝	32	88	32
2¾ ,, ½	12½	3½ ,, 11/16	20	6 ,, 1½	28	80	28
		3¼ ,, ⅝	18	5¾ ,, 1½	27	72	27
2 ,, ⅝	10	3 ,, ⅝	16	5½ ,, 1⅜	26	64	26
1⅞ ,, ½	8	2⅞ ,, 9/16	14	5¼ ,, 1¼	24	56	24
		2¾ ,, ½	12	5. ,, 1¼	22	48	22
		2 ,, ⅝	10	4 ,, 1⅛	20	40	20
		1⅞ ,, ½	8	3 ,, 1	16	32	16

Examiners: Let us have the strength of chains.—Applicant I will.

Table of the weight and strength of chains.

Diameter	Weight per Fathom	Proof Strength	Diameter	Weight per Fathom	Proof Strength
Inches	Lbs.	Tons	Inches	Lbs.	Tons
$\frac{5}{16}$	$5\frac{1}{2}$	1·27	$1\frac{1}{8}$	68	26
$\frac{3}{8}$	8	1·82	$1\frac{3}{16}$	76	29
$\frac{7}{16}$	$10\frac{1}{2}$	2·5	$1\frac{1}{4}$	84	32
$\frac{1}{2}$	$13\frac{3}{4}$	4·	$1\frac{5}{16}$	93	35
$\frac{9}{16}$	17	5·	$1\frac{3}{8}$	102	38
$\frac{5}{8}$	22	6·	$1\frac{7}{16}$	111	41
$\frac{11}{16}$	26	$7\frac{1}{2}$·	$1\frac{1}{2}$	120	44
$\frac{3}{4}$	30	10·	$1\frac{9}{16}$	128	48
$\frac{13}{16}$	36	$11\frac{1}{2}$·	$1\frac{5}{8}$	136	52
$\frac{7}{8}$	42	13·	$1\frac{11}{16}$	142	56
$\frac{15}{16}$	49	15·	$1\frac{3}{4}$	148	60
1	55	18·	$1\frac{13}{16}$	150	65
$1\frac{1}{16}$	60	22·	$1\frac{7}{8}$	162	70
			$1\frac{15}{16}$	171	75
			2	180	80

Examiners: We are glad to find you so well informed on the subject of mining, we hope a certificate as mine manager being granted, you will always be found worthy of such, by constant care and attention.—Applicant: It will ever be my greatest delight and pleasure to give satisfaction, to save life and property.

Mr. Hopton has prepared a large number of questions for applicants, which are published in a separate form.

P.S.—All practical men should now bestir themselves, and obtain the information required for taking the management of mines. They have got the practical knowledge, all they require is a theoretical knowledge. If mines are to be managed properly for safety and economy, men must be obtained with a knowledge both of the practice and theory of mining. A class of managers so qualified would be unequalled; and any person able to answer the preceding questions, and properly understand them, will not, I venture to say, be far from the mark, and should satisfy both examiners and employers, as well as the public.

W. HOPTON.

A LECTURE

ON

THE ATMOSPHERE;

ITS

CHANGES AND EXPLOSIVE GASES:

BY WILLIAM HOPTON,

"CERTIFICATED" MINE MANAGER.

The atmospheric air is the foundation of my discourse. When God breathed into man the breath of life, he gave him good, pure air to breathe. It was not given grudgingly, sparingly, nor scantily; but given plentifully, and in abundance.

It was given to sustain, to nourish, and to support him; and the more we know of its properties, the more we shall estimate its value and its worth, for it is one of the greatest blessings

God ever bestowed upon man; because it is useful for many things, if not useful for all things. The air we breathe maintains the clouds in the heavens, and gives buoyancy to the feathered tribes as they fly along through it. It raises balloons, smoke, vapour, and all noxious gases to the heavens.

It also throws back light, or gives a reflective power, by which objects are enlightened. It is owing to the atmosphere that the heavens appear bright in the day time; for, without it, only that part of the heavens would be light or luminous in which the sun is placed; and if we could live without air, and should turn our backs to the sun, the heavens would appear as dark as in the night time. This reflective power of the atmosphere is the means by which objects are enlightened so uniformly on all sides. The want of this reflective power would cause a strange alteration in the appearance of things, the shadows of which would be so very dark, and their sides, enlightened by the sun, so very bright, that, no doubt, we could see no more of them than their bright parts; and for a view of the other parts, we must turn them half round, or wait until the sun came round upon them.

But what would be the result, had we a world void, or destitute of air? In a world void, or destitute of air, the feathered tribes would have no use for their wings, for they could not fly; nor could a fish swim in the ocean—it would sink to the bottom. A cat, a mouse, or a bird in a room void of air, would expire in a few moments. To have a world void, or destitute of air, music would lose its charms; neither could the sound of bells and voices be heard; however loud we might call from the top of the voice, we could not be heard. To have a world void of air, the medium through which sound is conducted would be lost; and, if so, we should be no better than people who are deaf and

dumb. Everything would have to be conducted by signs and motions; but, I am glad we have not a world void, or destitute of air.

Having shown, briefly, a few useful properties of the air, I will now endeavour to show of what it consists.

The atmosphere is a compound, or a mechanical mixture; a compound is a mixture of ingredients, that is, several things mixed or blended together to make one, therefore, the atmosphere is a compound of two ingredients composed of two opposite principles. One ingredient is the source of flame and life; the other ingredient is destitute of both, yet producing, by their different combinations of mixtures, the most diversified, beneficent and good effects. These two ingredients of the atmosphere are termed oxygen and nitrogen gases. To give an explanation of the two gases, it will be well to show first the properties of oxygen, and then the properties of nitrogen.

Oxygen is not a combustible, but a supporter of combustion. That is to say, it is not like the gas found in coal mines, which explodes at a naked light; neither is it like the gas in the street, so that, if it filled a room, it might be exploded; not so, I say, with oxygen gas, it cannot be exploded, it only supports and feeds the flame.

If the air consisted of oxygen only, we could not make the poker very hot, but it would burn; nor could we extinguish a candle but by cutting off the wick; and, if a house should be on fire, the consequences must be awful indeed, as there would be no means of extinguishing the devouring element. If oxygen gas was left to exert its native energies, it would melt the hardest substances, and would set the earth in flames. Not only would such articles as wood and coal burn, but even stone,

iron, and other substances, would blaze with a rapidity which would carry destruction through the whole expanse of nature. This terrific oxygen would feed the flames on every side, and set at defiance the united efforts of every engine in the fire brigade; and water, in such an atmosphere, would have no power in extinguishing the flames, but only support the conflagration, as water in 100 parts is composed of 85 parts oxygen, and 15 parts hydrogen. Indeed, if the air consisted of oxygen only, the whole world must shortly be in one general conflagration; and it has been imagined that the earth may be consumed in this very manner at the last day, were the Author of nature to take away nitrogen from the air, and leave oxygen alone remaining. Nor could we breathe oxygen by itself; it would cause our blood to circulate with greater rapidity, and soon waste and destroy the human frame; therefore, we have some knowledge of what would be the result if our atmosphere consisted of oxygen only.

The other ingredient of the atmosphere is nitrogen, of which I have very little to say. If the air consisted of nitrogen only, every species of fire and flame would be extinguished, and all the tribes of animated nature instantly destroyed. Nitrogen neither supports combustion nor enables animals to live; therefore, as a component part of the atmosphere, it is made in order to temper down or dilute the excessive strength of the oxygen.

The Mixture of Oxygen and Nitrogen Gases.

The two gases of the atmosphere will not do, then, in a separate state, but mixed in such proportions as they now are by Providence, they supply the means of carrying out the great system of nature. The mixture is constituted as follows:—In

100 cubic feet there are 21 parts of oxygen and 79 parts of nitrogen. The mixture of these gases is everywhere and always alike, on the mountain and in the plain, in England and America, Africa or New Zealand—ever the same, 21 parts oxygen and 79 of nitrogen. It will not do, therefore, to have more or less of either of these gases. I know the atmosphere is daily deprived of its oxygen, by fires, combustion, and flame, and consumed also in the lungs by every person and animal that breathes the air; yet the Divine mind has not overlooked this great consumption of oxygen without providing an equivalent supply, which is obtained from the leaves of trees and other vegetables, which give off the quantity required, and no more, so that the mixture is nicely balanced and proportioned, continuing always and everywhere the same.

What an all-comprehensive, intelligent mind it shows! To cause one simple principle in different combinations of mixtures to produce so many important beneficial effects! What dreadful havoc would be produced in the whole system if such substances as oxygen were not nicely balanced and proportioned! These facts demonstrate the infinite knowledge and wisdom of the great contriver of the universe, in the nice adjustment of every circumstance so as to preserve the balance of nature, and to secure the happiness of his offspring.

Let us see what the effects would be if the mixture were to be altered.

To alter the mixture (by weight) from 21 to 37 parts of oxygen, and the nitrogen from 79 to 63 parts, gives what is called laughing gas, which, when inhaled into the lungs, will produce fits of laughing, leaping, running, and many other delightful emotions. Then, again, if the mixture were altered to 56 parts oxygen and

44 parts nitrogen, it would produce instant suffocation to all who attempted to breathe it.

These gases, producing such effects, compose the air we breathe, the only difference being in the mixing of them—adding and diminishing the quantities.

Having thus demonstrated the mixture, I will now speak of the weight or specific gravity of such gases, which is of equal importance.

The weight of oxygen is 1·1007, that is, near 33 grains to 100 cubic inches of the atmosphere. The weight of nitrogen is 0·9748, or near 30 grains to 100 cubic inches of the atmosphere. That is to say, the relative weight of the two gases is what a 33lbs. weight is to a 37lbs. weight, the nitrogen being a small degree lighter than the oxygen; and it is wisely contrived so to be, for were it otherwise, that is, were oxygen a small degree lighter than nitrogen, so that the latter would be a degree heavier than common air, it would occupy the lower regions of the atmosphere, and produce universal death; because, instead of ascending as it now does when thrown off by the lungs in breathing, it would descend to the surface of the earth, to be breathed over and over again.

Here we again perceive an admirable adaptation of means to an end, and from ignorance of such facts the bulk of mankind do not understand the blessings they enjoy.

Having given, then, a brief explanation of the atmospheric air as a compound, together with its mixture and weight, I will now speak of its expansive and contractive properties.

You know, by exerting sufficient force, a piece of india-rubber may be pulled or stretched out to three or four times its natural length, and, immediately that force is removed, it returns to its

original dimensions. I know we cannot take hold of and grasp the atmosphere as we can india-rubber, and pull it out, yet we can do that which amounts pretty nearly to the same thing. Mr. Boyle tells us that he expanded the air, with an air-pump, until it swelled out and occupied a space 14,000 times larger than it usually occupied; that is to say, the air swelled, or expanded out, until one cubic foot would fill a room thirty feet in length, thirty feet in width, and fifteen feet in height.

Again, another person informs us that he compressed or contracted the air, until it occupied a space 40,000 times less than it naturally occupied; that is to say, the air, in this case, was compressed until one cubic foot, or the same amount of the air which filled a room thirty feet long and thirty feet wide, by fifteen feet high, was pressed into a space only 1-24th part of an inch.

It is also said, that were it possible to transport a person from the earth, with the same pressure of air in his body as when on the surface, to a place five hundred miles high, one breath of air from his lungs would swell and expand out, until it would fill a sphere as large as this globe.

By what I have now stated, every person will see that the expansive and contractive properties of the air are very great. I must now leave the subject of expansion, having to speak of it again shortly. I will now speak of the height and weight of the atmosphere.

As we ascend into the higher regions of the atmosphere, we find our bodies pressed upon with less and less weight than on the surface of the earth; if, therefore, we were to ascend a mountain, or go up in a balloon, our bodies would be pressed upon with less and less weight than on the earth's surface, and with more and more weight as we descend.

In proof of this, a number of gentlemen once ascended in a balloon to a very great height; in doing so, their hands and feet were much swollen, so that the skin of their hands and feet had to be cut. Again, a number of gentlemen, in a journey among the mountains of Peru, were surprised to find that they had great pangs of straining and vomiting, and also casting up of blood; and, no doubt, had they remained two or three hours longer, they would have died. That shows that if we ascend to a very great height, the pressure of the atmosphere on our bodies is so reduced, that it is not sufficient to counter-balance the pressure of the fluids in the body.

The atmosphere, then, is considered to be forty-five miles high: this height is known, as before stated, by the weight of it diminishing and increasing as we ascend and descend; therefore, the atmosphere must press upon itself, so that the nearest yard of air to the surface of the earth is pressed upon by the whole weight of the air above.

I will illustrate this subject a little; therefore let us imagine that, instead of a layer of the atmosphere forty-five miles high, we have a number of wool packs the same height. If such be the case, will not the nearest pack to the ground be pressed upon by the weight of all above, and also pressed into a much smaller space than the uppermost one? Just in like manner, then, the lower part of the atmosphere is pressed upon by the whole weight of that above.

It is evident we live, then, at the bottom of a very deep sea, a sea forty-five miles deep, not of water, but a deep sea of air, and at the bottom of this deep sea, there is a great weight always pressing upon bodies and substances which lie on its floor, or the earth's surface. Now, the average weight of air pressing on the

earth's surface is fifteen pounds per square inch, or 2160 pounds upon every square foot; and, as the area of the whole earth's surface is near two hundred millions of square miles, the total weight of air pressing on this globe is twelve trillions, forty three thousand four hundred and sixty eight billions, and eight hundred thousand millions of pounds; or five thousand billions of tons.

Five thousand billions are very soon said, yet the quantity is too great for any person to conceive. It would find employment for all the people in England, men, women, and children, to count the number in twelve months, and work hard twelve hours each day. Such is the weight of air pressing on the earth's surface

Living, then, as we are, at the bottom of this deep sea of air, it is evident the pressure on our bodies is very great; it is estimated at near fourteen tons; yet a small quantity of air within the human body, which will not weight above a single ounce, will, by its strong elastic force, counteract the effect of this tremendous pressure, and prevent it being crushed to pieces. A room is full of air, and were it not for the strong elastic force of it within, counterbalancing the weight of that without, we should all be crushed to death by the falling of the building; and every glass window would be shattered to atoms. It is this great weight of the atmosphere which raises water in our forcing pumps, and supports quicksilver in barometers, and also prevents the water in our seas and rivers from boiling, and evaporating into steam. Take the pressure away, and all liquids would at once boil; therefore, the pressure keeps the steam down, and prevents boiling.

Liquids may be made to boil by two methods; we may either take away the pressure, and allow the natural heat of the liquids to act, or add so much additional heat to overcome the pressure.

This weight of the atmosphere is the earth's great boiler valve, preventing the outbursts of gases pressed and pent up in the earth's strata. Let the Author of the universe remove away this pressure, and the whole globe would shortly be in flames. The whole earth's strata, like steam in a boiler, is pressed with gases to overflowing, and only prevented from a tremendous outburst by the atmosphere being equal in weight to the pressure of the gases therein; then remove it, I say, and the earth would shortly be in flames. I know many people will say it is all a delusion, because the pressure of the atmosphere on their bodies is not felt; yet what I have stated is certainly the case.

How this pressure acts on pumps.

A respectable gentleman in Scotland applied to a friend, in order to obtain his advice respecting a pump, which he had constructed at a considerable expense. He told him that, notwithstanding every exertion, he could not obtain a drop of water, although he was sure there was plenty in the well, and although he had plastered it all around, and blocked up every crevice. When the well was inspected, it was found to be air-tight, so that the atmospheric pressure could not act on the surface of the water; but an orifice was at once made in the well, and water flowed from the spout abundantly. Again, one of the Grand Dukes of Tuscany wished to pump water from a very deep well, but having erected his pump, it was found that the water would not rise in the pump-barrel. This very much surprised his highness, and he called together the philosophers, in order that the mystery might be solved. Now, the opinion hitherto of the rise of water in a pump-barrel was, that nature abhorred a vacuum, but why it did not rise for the Grand Duke was a

mystery. The pump-makers were then questioned, and they affirmed that water never would rise more than thirty-four feet, but why it was so they could not tell. Matters remained in this state until one of the pupils of Galileo undertook the investigation, and he made this important discovery,—that just as water could not be pumped more than thirty-four feet, neither could quicksilver be pumped more than thirty inches, because the weight of the atmosphere, pressing on the surface of the water, balances that in the pump-barrel, therefore, by every stroke of the pump it takes away its load, but it is the atmospheric weight which supplies it with another load of water as often as it removes one.

How this pressure acts on barometers.

Just on the same principle, then, mercury is also balanced in the tube of a barometer by the atmospheric weight. I say balanced, because it is just on the same principle as two weights in a pair of scales, the mercury being in one scale, and the atmospheric weight in the other, so that thirty inches of mercury, and thirty-four feet of water, balance a weight of air forty-five miles high.

You have seen that the mercury in the tube of a barometer moves up and down; now the cause of this is changes that from time to time take place in the atmospheric pressure, so that when the mercury moves upwards the atmospheric pressure is increased, but diminished when it falls down. This change in the atmospheric weight is just on the same principle as tides of water in the ocean. Tides of water roll along from one part of the ocean to another, by which its weight varies in proportion to its depth. So, I say, we have tides of air rolling along from one part of the globe to another, and as this atmospheric tide rolls along, its weight varies accordingly. These tides in the atmosphere are

caused by the rise and fall of the temperature in separate parts of the globe. The air expands and swells out in one part of the globe in consequence of a rise in the temperature; in another part it contracts into less space by a fall of temperature. And it is owing to this atmospheric contraction and expansion that currents of air, or wind, move from one part of the globe to another. Now, these winds on the surface show the great wisdom of God. Had it been otherwise, smoke, vapour, noxious gases, chemical stenches, and other smells, would remain in the places whence they were emitted, producing universal sickness and death.

How this change in the atmospheric weight affects mines.

Now, this variation in the weight of the atmosphere affects greatly the gases generated in mines, on the same principle as steam discharged from a boiler. If, when steam is blowing off from a boiler, you at the same time take a little weight off the valve, an extra quantity will be discharged. Atmospheric weight, then, is the earth's great boiler valve, preventing the outburst of gases pent up within the earth's strata. Now, when this weight, which is, say, 15 lbs. to-day, is reduced to 14 lbs. to-morrow, an extra discharge of gases takes place in mines.

If what I have just stated be correct, there is another question to solve, that is to say: If this atmospheric pressure be simultaneously reduced in all mines, and the discharge of gas takes place from all, how is it that each mine does not discharge an equal quantity of gas? I will explain this by a simple illustration. Suppose we had three boilers full of steam, the weight on each valve being 15 lbs. The steam in one boiler so compressed that a great quantity of steam is discharged; the next, not so com-

pressed, blows off less steam; and the third, being but slightly compressed, discharges very little steam. Now, if 1 lb. weight be taken from each valve, the greatest discharge of steam will be from the boiler most compressed. And so, when the atmospheric pressure is reduced from all, the greatest quantity of gas will be discharged from the mines that are most compressed.

Again, if the atmospheric pressure is the same on all mines, how is it that the compression of gases is not alike in all? I answer, because explosive gas has been discharged from one mine for a longer period than from another, diminishing the compression in proportion; just in the same manner as steam being less compressed in the boiler which has been longest blowing off. From what I have stated it will be understood that one mine discharges more gas than another in proportion to the time which such discharges occupy, or the strata to surface more open.

Mines vary not only in the quantity, but also in the quality of their gases. One discharges pure explosive gas, another a mixture of the two gases called explosive gas and black damp, while a third discharges black damp alone. It may be asked why mines vary in the quality of gases discharged; which may be explained in the following manner:—Suppose we had a mine newly opened out, in which the explosive gas in the strata is so strong as to overpower for a time the atmospheric weight, it will discharge a large quantity of gas until its compression is reduced more and more to the weight of the atmosphere, after which the discharge of explosive gas will be only occasional, according to the changes in the atmospheric weight, which to-day is 15 lbs., and to-morrow may be reduced to 14 lbs., a proportionate discharge then taking place. Consequently, when

the atmosphere returns to its former weight of 15lbs., the air itself is forced into the strata to fill up the space vacated by the gas when the atmospheric weight was lowest; the air then works in and out of the strata, backwards and forwards, and mixes with the gas therein, as the same reduced pressure which caused the gas to expand and rush out will also force the air in. The weight of air never being long at a standstill, it works backwards and forwards, into and against the strata, like a person drawing in and letting out his breath. By this forcing of atmospheric air into the strata, a mixture of explosive gas and black damp is generated, which is discharged at intervals until all the explosive gas is exhausted, after which the mine discharges black damp only. In the same manner a person lets air into his body by breathing, and that air is converted into nitrogen or carbon before it is discharged. By what I have just stated, you will understand why one mine discharges pure explosive gas, another a mixture of the two gases, and a third black damp only.

Again, gases do not vary in quality and quantity only, but also in weight, and this variation very much affects mines. I will now show the weight of those gases, and how they affect mines. The weight, or specific gravity of the atmosphere, is 1·000; therefore, one foot of it will weigh nearly two feet of explosive gas, because the specific gravity of explosive gas is 0·555. Explosive gas, then, being so much lighter than air, is the cause of its so affecting mines, because it makes its way up into every hole in the roof, and all very high workings; and like corkwood in water, or a balloon in the air, it rises to the top of all such workings, and overflows them, and to bring the gas away a propelling force in the air current is required, as well as quantity.

Again, one foot of black damp will weigh nearly three feet of explosive gas, because the specific gravity of black damp is 1·524, and as such is the case, it settles downwards to the floor, like mud in water, and fills the lowest working places, and to bring it also up therefrom, a propelling force in the air current is required as well as quantity; if not, the gas will not mix with the air, but pass through and leave it there.

Let every fireman, deputy, underlooker, and manager, then, remember such laws of nature, and never depart from them. For the fixing of brattice cloth to propel downwards explosive gas from any high working place, the cloth must be so arranged that the largest space for the current to pass must be in going to the gas, and the least space in coming from it, so that force may be obtained in the return current; if not, the air will pass through the gas, and not bring it away. Then again, for the bringing up of black damp from below, out of deep workings, the space behind the brattice cloth must be least in coming from, and largest in going to it, so that force in the return current, as well as quantity, may be obtained. When this is not attended to, miners often work in jeopardy when it might at once be removed.

I will now speak of the composition and mixture of those mine gases. Fire-damp is a composition of two gases, termed hydrogen and carbon; the two being mixed together form the carburetted hydrogen gas called fire-damp. In five feet of this gas four parts of it consist of hydrogen gas, and one part of carbon.

Again, when an explosion of this gas takes place, another gas is produced, which we call after-damp, or choke-damp; this after-damp is also a composition of three gases—viz.,

nitrogen, carbonic acid, and watery vapour. In eleven parts of after-damp, one part consists of carbonic acid, two parts of watery vapour, and eight parts of nitrogen.

What can fire-damp, then, be obtained from? I answer, from water and wood, because hydrogen is one of the ingredients of water, and carbon is also one of the ingredients of charcoal; therefore, the two ingredients of fire-damp can be obtained from water and wood.

Also, what can after-damp be obtained from? I answer, from air, water, gingerbeer, and wood, because nitrogen is one of the ingredients of the air, and carbonic acid is one of the ingredients of ginger-beer and of charcoal. Watery vapour, the other ingredient, is water when condensed; so that after-damp can be obtained from air, water, gingerbeer, and wood.

What effect does after-damp produce on a person when breathed? The following: Carbonic aid gas is a positive poison; nitrogen merely poisons by excluding oxygen: that is to say, carbonic acid lays violent hands upon its victim, and at once kills him, while nitrogen starves him to death by excluding all nourishment; therefore, it is death to all who breathe after-damp. When breathed, it takes away a person's strength, his limbs fail him—they become heavy and powerless, he then feels a deathlike sickness, yet without pain, and at last he passes away insensibly, like a person going to sleep, and in that state he enters eternity. I have a knowledge of the effect it produces, having been for a long time insensible through breathing it.

Again, as to the explosive mixture fire-damp. I have before stated that fire and flame are supported by the oxygen in the air. If flame could exist without oxygen, the blaze at the end of a gaspipe would pass through and along to the whole magazine of

gas, and nstantly explode it; but no! it is impossible, oxygen in the air is required to feed it. A proper mixture, therefore, of explosive gas with oxygen is required to cause an explosion. I say a proper mixture, because the power of an explosion is in proportion to the mixture as well as to the quantity of such gases. The greatest explosive power is obtained when one foot of fire-damp is mixed with say seven of air, but an explosion will take place when one foot of fire-damp is mixed with from four to twelve feet of air; therefore, it requires a larger quantity of air than gas to cause an explosion, and a larger quantity of air than gas to prevent one. So that gas, you see, is rendered harmless by adding more pure air into the same quantity of gas, that is to say, it becomes further from the explosive mixture. Gas is not destroyed, it is only rendered harmless, by a large admixture of atmospheric air: the old goaf, and other places charged with gas to overflowing, cannot be ignited if the atmosphere is not allowed to mix with it. This I have several times proved to be correct.

Many know not why the Stephenson safety-lamp becomes extinguished in a mixture of fire-damp. It is because the lamp is so constructed with air-passages as to admit only just the quantity of air required to feed the flame, and an explosion taking place within the lamp enlarges the flame, and an enlarged flame requiring more air, which the passages do not supply, it dies out just as a person would die for the want of food.

My next subject is ventilation. What are we to understand by it? or how is a current of air to descend one shaft and pass up another? This may be better understood by a very simple illustration of two weights in a pair of scales. Suppose, then, we had a pair of scales with a 15 lbs. weight in each scale, in that case, the weight at each end being equal, the scales would

be perfectly balanced; but if we add one pound to one, making it 16 lbs., that weight would over balance the other; and the same effect would be produced by taking off a pound from one end, reducing it to 14 lbs. What I wish you to understand by this simple illustration is this: Remembering that the 15 lbs. of atmospheric weight press alike on the top of one shaft as on the top of another, and as two 15 lbs. weights cannot overbalance each other without either adding or diminishing, so a current of air cannot pass down one shaft and up another, but remains at a standstill, unless weight be added to or taken from the atmospheric pressure at the top of one of the shafts. You will now understand how a current of air is produced, and caused to pass down and around the workings of a mine.

As there are several ventilating powers, I will briefly mention a few of them:—

1. The force of the wind blowing on the surface is one power, because the air propelled into a hopper at the top of a shaft adds an increased weight in that shaft or scale, by which a current of air is produced for the workings.

2. A waterfall in one shaft propels a force of air which adds more weight to that scale, by which a current is produced.

3. A ventilating fan produces ventilation by its revolving force, because it adds to or diminishes the atmospheric weight, and by so doing propels downwards or upwards a current of air for the workings.

4. The cylinder of a ventilating engine propels a force of air, up or down, with every stroke of the piston, which produces a current.

5. In giving an explanation of the furnace-power, I must return again to the subject of expansion and contraction, because

the power of the furnace is in proportion to the amount of heat raised to the largest volume of cold air; therefore, if we fill a bladder with say 480 cubic inches of the air at a temperature of 32 degrees, every degree of heat added to the air in the bladder would cause it to swell out one part more, so that when the temperature had risen from 32 degrees to 152 degrees, the 480 parts of air would have swelled out to 600 parts, or expanded one-fifth, and the weight would be one-fifth less in the space at first occupied.

By a simple illustration I think I can show this subject a little more clearly. Suppose we had a pair of scales, so large and so constructed, that we could weigh all the cold air in the down-cast shaft, and weigh in the other scale all the hot air that filled the up-cast; if so, we should find the cold air in the down-cast scale would overbalance very much the hot air in the up-cast scale. By this simple illustration you will now understand that the furnace heat swells out the air in the up-cast, by which it becomes much less in weight than the cold air in the down-cast, for the space occupied; therefore, if one foot of cold air expands, by heat, into two feet, the two feet, you know, will only weigh the same weight as one foot before. Heat, then, makes air so light by expansion, that it rushes up one shaft like corkwood in water, or a balloon in the air, and the cold air in the down-cast is too heavy to remain in its place, it falls down, and rushes through the workings to occupy the place of the hot air: therefore, to produce a great current of air, the furnace should be fixed where it can heat the largest volume of cold air, as its power is accordingly.

Before I leave this subject, I must tell you that the furnace power is affected much by changes of temperature on the surface,

from winter to summer; because its power, as before stated, is in proportion to the number of degrees of heat raised betwixt the down and up-cast shafts; that is to say, if the furnace should raise the temperature in the up-cast to, say one hundred and forty-two degrees, at a time when on the surface the temperature was at, say thirty-two degrees, this will show a nett ventilating power of one hundred and ten degrees. But in summer if the temperature on the surface should rise to, say eighty degrees, the nett ventilating power of the furnace would be then only sixty-two degrees, because you take eighty from one hundred and forty-two; this will show that a change from winter to summer, or any sudden fall in temperature, affects much the furnace power and currents in mines.

By what I have now stated, you will understand when mines are in the greatest danger. When the barometer falls it shows that this weight in the atmospheric valve is diminished, by which an extra outlet of gases is discharged. Also, a rise in the thermometer shows an increased temperature on the surface, and, by this increased temperature, the ventilating power is diminished, by which the underground currents are also diminished: those two changes suddenly taking place at one and the same time, affect very much the workings of mines with gases. One is the cause of an extra discharge of gases; the other diminishes that current of air which should take the gases away.

We now come to the subject of ventilation, or, to the distribution of the ventilating currents, a subject which has caused much controversy. To distribute the ventilating currents properly, for the safe conducting of gases through and around the workings, requires the greatest caution and care; because the atmospheric changes are often and many; the opening and

closing of doors, the up-lifting, squeezing, and heaving and falling, also, of the air gates; together with the number of lights exposed, and sudden outlets of gases taking place, much caution and care is required, so that it is next to an impossibility to keep, at all times, every person away from danger; therefore, it is well, then, to keep as far as possible the danger from them, because there is a right and a wrong way of conducting gases away from the men, and through the workings of a mine.

By ventilation, you may either throw all the gases discharged upon every workman employed, or conduct them away. I think I can make this subject a little more clear by a simple illustration. Suppose a number of chemical works are near a large population, who are affected by breathing impure air every time the wind blows from the works towards them, but in case a change in the wind takes place, so as to blow the gases in an opposite direction, if its force be not one-twelfth of that which blew the gases to them, yet, by this change of the wind, all will breathe a purer air, as no gas can come against the wind, be its velocity ever so small.

And so, in like manner, is the ventilation of mines; the ventilating current should be conducted pure into the workings, to convey, as far as possible, the gases away, and not conduct them into the tramroads and upon every person employed. There are several systems of ventilation, but I propose to glance for a short time only at the separate current system; in doing so, I ask, what amount of air can be produced per minute for the whole workings of a mine? 20,000 feet, 40,000 feet, 60,000 feet, 80,000 feet, or 100,000 feet, be that amount less or more, all should not be sent in one current around the workings of a mine.

Divide, split, or separate it into distinct currents, or parts of

say from 4,000 to 6,000 feet of pure air for each division; after which, if ten, fifteen, or twenty miners are getting coal in one district, supply the said number of miners with one distinct current of pure air, fresh from the down-cast, after which conduct the said current away safe to the up-cast, and do not, if possible, ventilate other workings with it afterwards. Then again, supply another current of fresh pure air to another group of miners, and conduct the said current as before, direct to the up-cast; and so on, in a similar manner, supply each party of miners with fresh distinct currents of pure air.

By splitting into parts you divide the explosive power, as gas is prevented by this system from collecting in large quantities, because, if one hundred feet of gas were discharged per minute from one group of miners, we might have five hundred feet discharged in the workings of five groups of miners, and to ventilate all with one current, the whole volume of five hundred feet of gas might be ignited at once; but not so if ventilated separately, only one-fifth would be ignited; if so, the power of the explosion would be reduced to one-fifth, the danger to a person's life reduced to one-fifth, therefore, why not ventilate with separate currents? Yet do not misunderstand, and think I am of opinion there never will be explosions; I answer, there always were and always will be explosions; yet, if a proper system of ventilation were adopted, the loss of life and property would not be so great when they did take place.

SUMMARY

OF A FEW

SERIOUS ACCIDENTS SINCE THE YEAR 1710.

DATE.			COLLIERY.	CAUSE.	LIVES LOST.
About 1710			Bensham	Exploded.	70 to 80
1743	Jan.	18	North Biddick	Do.	17
1757	June	10	Ravensworth	Do.	16
1766	Mar.	18	Walker	Do.	10
1767	Mar.	27	Fatfield	Do.	39
1778	Dec.	8	Dolly Pit, Chaytor's Haugh .	Do.	24
1794	June	9	Rickleton Pit, near Picktree	Do.	30
——	June	11	Harraton	Do.	28
1795	April	24	Paradise or West Pit, Benwell	Do.	11
1799	Oct.	11	Lumley	Do.	39
1803	Sept.	25	Wallsend	Do.	13
1805	Oct.	21	Hebburn	Do.	35
——	Nov.	29	Exclose	Do.	38
1806	Mar.	28	Killingworth....................	Do.	10
1809	Sept.	14	Killingworth.....................	Do.	12
1812	May	25	Felling	Do.	92
——	Oct.	10	Herrington Mill Pit, Pensher	Do.	24
1813	Sept.	23	Hall Pit, Fatfield......	Do.	32
——	Dec.	24	Felling	Do.	22
1814	Aug.	12	Hebburn..........................	Do.	11
1815	May	3	Heaton Main....................	Inundation	75
——	June	2	Success Pit, Newbottle	Exploded.	57
——	June	27	Sheriff Hill	Do.	11
1817	June	30	Row Pit, Harraton	Do.	38
——	Dec.	18	Plain Pit, Rainton	Do.	27
1819	July	19	Sheriff Hill	Do.	35
——	Oct.	9	George Pit, Lambton	Do.	13
1821	Oct.	28	Wallsend (Russell's)	Do.	52
1823	Nov.	3	Plain Pit, Rainton	Do.	59
1824	Nov.	19	Dolly Pit, Newbottle	Do.	11
——	Oct.	25	George Pit, Lumley............	Do.	14
1825	July	3	Judith Pit, Fatfield...........	Do.	11
1826	Jan.	17	Jarrow	Do.	34

DATE.			COLLIERY.	CAUSE.	LIVES LOST.
1826	May	30	Townley..........................	Exploded.	38
1828	Nov.	20	I Pit, Washington	Do.	14
1830	Aug.	3	Jarrow	Do.	42
1833	May	9	Springwell	Do.	47
1835	June	18	Wallsend	Do.	102
1836	Jan.	28	Hetton Colliery	Do.	20
1839	June	28	Hilda Wallsend, South Shields	Do.	50
1840	Jan.	24	*Rothwell Haigh, Leeds	Do.	7
1844	Sept.	28	Haswell	Do.	95
1845	Aug.	21	Jarrow Colliery	Do.	39
1850	Nov.	11	Houghton	Do.	26
1851	Mar.	15	Nitshill, Scotland...............	Do.	61
——	Aug.	19	Washington	Do.	28
——	Oct.	31	Killingworth	Do.	9
——	Dec.	20	Warren Vale Colliery, Rotherham	Do.	52
1852	May	—	Hebburn	Do.	23
1853	Mar.	24	Ince Hall Arley Mine, Wigan	Do.	58
——	April	26	Old Park Colliery, Dudley...	Do.	11
——	July	1	Bent Grange Colliery, Oldham	Do.	20
1855		—	Middle Duffryn	Do.	68
1856		—	Cymmer Colliery..	Do.	114
1857	Feb.	19	Lund-hill	Do.	189
1860	Mar.	2	Burradon	Do.	74
——	Dec.	7	Risca, South Wales............	Do.	130
——	Dec.	20	Hetton	Do.	22
1861	July	—	Clay Cross........................	Inundated.	23
1862	Jan.	16	Hartley	By breaking of engine pump beam.	204
——	Mar.	—	Gethin	Exploded.	47
——	June	2	Bilston	Inundated.	7
——		—	Washington	Exploded.	28
——		—	Guindraeth, South Wales...	Do.	27
——		—	Coppul	Do.	36
1866		—	Bedwellty Colliery	Do.	21
——	Dec.	12, 13	Oaks Colliery	Do.	362
——	Dec.	13	Talk-o'-th'-Hill	Do.	91
1867	Nov.	8	Ferndale Colliery	Do.	17

* At this colliery the father of William Hopton, the author of this book, was lost.

USEFUL TABLES.

Weights and Measures.

The origin of all *Weights and Measures* in England was derived from a grain of wheat; vide statutes of 51 Henry III., 31 Edward I., and 12 Henry VII., which enacted that 32 of them, well dried, and gathered from the middle of the ear, were to make 1 pennyweight; 20 dwts. 1 oz.; and 20 oz. 1 pound.

It was subsequently thought better to divide the *pennyweight* into 24 equal parts, called *grains*.

William the Conqueror introduced into England what was called Troy Weight, from Troyes, a town in the province of Champagne, in France (now in the department of Aube), where a celebrated fair was held. The English were dissatisfied with this weight, because the pound did not weigh so much as the pound in use at that time in England. Hence arose the term, *Avoir du poids*, which was a medium between the French and the ancient English weights.

AVOIRDUPOIS WEIGHT was first made legal in the reign of Henry VII., and its particular use was to weigh provisions and coarse heavy articles. Henry fixed the stone at 14lbs., which has been confirmed by a recent Act of Parliament.

With respect to MEASURES OF LENGTH, it is recorded that the various denominations were constructed from *a corn of barley*, 3 of which, well dried, from the middle of the ear, made an inch. Other terms were taken from portions of the human body, such as the *Digit* (¾ of an inch, or a finger's breadth), a *Palm* (3 inches), a *Hand* (4 inches), a *Span* (9 inches), a *Foot* (12 inches), and a *Cubic* (18 inches), being the length of the arm or bone from the elbow to the wrist. A *Pace* (5 feet), or 2 ordinary steps; a *Fathom* (6 feet), from the extremity of one hand to that of the other, the arms are oppositely extended. It is stated that Henry I., in 1101, commanded that the ulna, or ancient ell, which answers to the modern yard, should be made the length of his arm; and that the other measures of length were hence derived, whether *lineal*, *superficial*, or *solid*.

All MEASURES OF CAPACITY were first taken from Troy Weight, and several laws were passed in the reign of Henry III., enacting that 8lbs. Troy of wheat, taken from the middle of the ear and well dried, should make one gallon of Wine measure, and 8 such gallons make a bushel.

Weights and measures were invented 869 B.C.; fixed to a standard in England, A.D. 1257; regulated, 1492; equalised, 1826, *agreeable to the Act of Uniformity which took effect 1st Jan.*, 1826.

The term *Measure* may be distinguished into several kinds, viz:—*Length, Surface, Volume, Specific Gravity, Capacity, Space, and Time and Motion.*

The several Denominations of these Measures have reference to certain *standards*, which are entirely arbitrary, and consequently vary among different nations. In this kingdom the *standard* of

Length is a *Yard*.
Solidity is a *Cubic Yard*.
Surface is a *Square Yard*, the $\frac{1}{4840}$ of an acre.
Capacity is a *Gallon*.
Weight is a *Pound*.

The standards of *Angular Measure* and of *Time* are the same in all European and most other countries.

The *Imperial Standard Yard* and the *Imperial Standard Pound Troy* having been destroyed in the fire at the Houses of Parliament in 1834, *Restored Standards of Weights and Measures* have been legalised by 18 and 19 Vic., cap. 72.

1.—Measures of Length.

The *Restored Standard* of Lineal Measure, whose length is called a yard, is a solid square Bar, thirty-eight inches long and one inch square, in transverse section, the Bar being of bronze or gun metal, at the temperature of 62 deg. of Fahrenheit's Thermometer—marked Copper 16 oz., Tin $2\frac{1}{2}$ oz., Zinc 1 oz.—and near to each end a cylindrical hole is sunk, to the depth of half-an-inch; the distance between the centres of the two holes being 3 *Feet*. or 36 inches, or one *Imperial Standard Yard*. The Standard *square* and *cubic* measures will therefore depend entirely upon it.

At present we have no means of ascertaining why this particular length was originally fixed upon; but, as it is most essential that it should always remain the same, it will be found convenient to refer it to something else, which we have no reason to suppose ever undergoes any change.

Now the length of a *Pendulum* vibrating *seconds*, or performing 46,400 oscillations in the interval between the sun's leaving the meridian of a place and returning to it again, is always the same at a *fixed* place, and under the *same* circumstances; and if this length be divided into 391,392 equal parts, the yard is *defined* to be equivalent to 360,000 of these parts; also, conversely, since a yard is equal to 36 inches, it follows that the length of the seconds pendulum, expressed in inches, is 39·1392.

The *Pendulum* referred to in this country is one vibrating seconds at *Greenwich* or in *London*, at the level of the sea in a non-resisting medium; and if the *standard yard* be at any time lost or destroyed, it would be easy to have recourse to experiment for its recovery.

The *Standard Yard* being the general *Unit* of lineal measure, it follows that all lengths less than a *yard* will be expressed by fractions; and it is on this account that a lineal *inch*, or *ten thousand* of the aforesaid portions of the *pendulum*, is conveniently adopted as the *unit* of lineal measure when applied to small magnitudes.

Hence also, by the same means, the *standard superficial* and *solid* measures will be accurately ascertained and kept correct.

LINEAL MEASURE.

12	Inches	=	1	Foot (ft).
3	Feet	=	1	Yard (yd).
$5\frac{1}{2}$	Yards	=	1	Rod, or Pole (p).
40	Poles, or 220 yards	=	1	Furlong.
8	Furlongs, or 1760 yards	=	1	Mile.

By this measure are computed the lineal dimensions of all magnitudes, with the exception mentioned below.

The *length* of a mile is not the same in every country. The Scotch and Irish miles were formerly about $1\frac{3}{4}$ miles English, but are now the same as English. A Spanish and Polish mile is about $3\frac{1}{2}$ English. A Swedish, Danish, and Hungarian mile is from 5 to 6 English miles. A Russian mile or verst is about $\frac{2}{3}$ of an English mile, and the French toise is about 6 feet.

The Dutch mile		=	8101 Yards.
Roman		=	1628 „
Arabian		=	2148 „
Persian Parasang		=	6086 „
$1\frac{1}{12}$	Inches	=	1 Line.
$\frac{1}{3}$	Inch	=	1 Barleycorn.
3	Inches	=	1 Palm.
4	Inches	=	1 Hand.*
$7\frac{23}{25}$	Inches	=	1 Link.
9	Inches	=	1 Span.
18	Inches	=	1 Cubit.
$2\frac{1}{2}$	Feet	=	1 Pace.†
5	Feet	=	1 Geometrical Pace.
6	Feet	=	1 Fathom.‡
$5\frac{1}{2}$	Yards	=	1 Rod, Pole, or Perch.
4	Poles, or 22 Yards	=	1 Chain.
3	Miles	=	1 League.
60	Geographical miles, or $69\frac{1}{2}$ English miles	=	1 Degree (or °).
360	Degrees	=	The circumference of the Globe, or any Circle.

CLOTH MEASURE.

This measure is used for all kinds of cloth, muslin, ribbon, &c.

The *Yard* in Cloth measure is the same as in Long Measure, but differs in its divisions and sub-divisions.

* The *Hand* is used for measuring the height of horses.

† The *Pace* is a measure taken from the space between the two feet of a man in walking, usually reckoned at $2\frac{1}{2}$ feet, but the *Geometrical Pace* is 5 feet.

‡ The *Fathom* is used in sounding to ascertain depth, &c., and for measuring cordage.

2¼	Inches		1 Nail.
4	Nails	=	1 Quarter.
4	Quarters	=	1 Yard.
3	Quarters	=	1 Flemish Ell.
5	Quarters	=	1 English Ell.
6	Quarters	=	1 French Ell.

II.—Measures of Surface.

The *Imperial Square Yard* contains 9 imperial square feet, and the *Imperial Square Foot* 144 imperial square inches; the *Circular Foot* (that is, a circle whose diameter is 1 foot) contains 113·027 square inches; and the *Square Foot* contains 183·346 circular inches (that is, circles whose diameters are each 1 inch).

SUPERFICIAL MEASURE.

144	Sq. Inches	=	1 Sq. Foot.
9	Sq. Feet	=	1 Sq. Yard.
30¼	Sq. Yards	=	1 Sq. Pole.

This measure is used for all kinds of superficial measuring, such as land, paving, flooring, roofing, tiling, slating, plastering, &c., and anything having length and breadth only.

Flooring, roofing, thatching, &c., are measured by the square of 100 feet, and bricklayers' work by the pole of 16½ feet, the square of which is 272¼ feet, though this is partly a cubic measure, as the brickwork is reckoned to be 14 inches, or 1½ brick thick.

LAND MEASURE

40 Sq. Poles	=	1 Sq. Rood.
9 Sq. Roods, or 4840 Sq Yards	=	1 Sq. Acre.
640 Sq. Acres	=	1 Sq. Mile.
30 Sq. Acres	=	1 Yard of Land.
100 Sq. Acres	=	1 Hide of Land.
40 Hides	=	1 Barony.

The dimensions of land, or of any surface of considerable extent, are taken by means of *Gunter's Chain*, which is 4 poles or 22 yards in length, and is divided into 100 equal parts, called *links*.

III.—Measures of Volume.

The *Imperial Cubic* (or solid) *Yard* contains 27 imperial cubic feet, and the *Imperial Cubic Foot* contains 1728 imperial cubic inches. The *Cylindrical* foot (that is, a cylinder 1 foot long and 1 foot in diameter) contains 1357·17 cubic inches. The *Spherical* foot (that is, a sphere 1 foot in diameter) contains 904·78 cubic inches; and a *Conical* foot (that

is, a cone 1 foot in height and 1 foot in diameter at the base) contains 452·39 cubic inches. The *Cubic* foot contains very nearly 2200 cylindrical inches (that is, cylinders 1 inch long and 1 inch in diameter); it contains very nearly 3300 spherical inches (that is, spheres 1 inch in diameter); and it contains very nearly 6600 conical inches (that is, cones 1 inch in height and 1 inch in diameter at the base).

SOLID OR CUBIC MEASURE.

A *Cube* is a solid body, and contains length, breadth, and thickness; having six equal sides. A *Cube number* is produced by multiplying a number twice into itself; thus, 64 is a cube number, and is produced by multiplying the number twice into itself, as $4 \times 4 \times 4 = 64$.

1728 Cubic Inches	=	1 Cubic Foot.
27 Cubic Feet	=	1 Cubic Yard.
40 Cubic Feet of Rough or 50 Cubic Feet of Hewn Timber	=	1 Ton or Load.
42 Cubic Feet of Timber	=	1 Shipping Ton.
108 Cubic Feet	=	1 Stack of Wood.
128 Cubic Feet	=	1 Cord of Wood.

IV.—Standard of Specific Gravity.

WEIGHT AND MEASURE OF WATER AT THE COMMON TEMPERATURE.

1 pint=34·65 cubic inches, or 1·25 lbs.
1 gal.=277·274 cubic inches, or 10lbs.
11·2 gals.=1 cwt.
224 gals.=1 ton.
1 cubic inch=252·45 grs., or ·03617 lbs.
12 „ inches=·434 lbs.
1 „ foot=6·25 gals., or 1000 oz., or 62·5 lbs.
1·8 „ „ =1 cwt.
35·84 cubic feet=1 ton.
1 cylindrical inch=·02842 lbs.
12 „ inches=·341 lbs.
1 „ foot=5 gals., or 49·1 lbs.
2·282 „ feet=1 cwt.
45·64 „ „ =1 ton.
1 cubic inch of mercury 34 25·25 grs.

The *Imperial pound avoirdupois*, which is the standard unit by means of which all heavy goods of large masses are weighed, is *defined* to be the weight of *one-tenth* part of an imperial gallon, or 27·7274 cubic inches of distilled water, ascertained at a time when the barometer stands at 30 deg., and the height of *Fahrenheit's* thermometer is 62 deg.; and this standard may consequently be verified or recovered at any time, when it may be necessary to appeal to experiment.

If the weight of a cubic inch of distilled water be divided into 505 equal parts, and each of such parts be defined to be a *half-grain*, it follows that 27·7274 cubic inches contain very nearly 7000 such grains; and it is hence declared by Act of Parliament that 7000 *grains* exactly shall hereafter be considered as the *pound* avoirdupois; and that 10 *grains* shall be equivalent to 1 *scruple;* and 3 *scruples* to 1 *drachm;* but the latter denominations are seldom necessary unless great nicety be required.

This weight receives its name from *avoirs*, the ancient name for *goods and chattels*, and *pois* signifying *weight*, in the ordinary language of the country at the time of the *Normans*.

The *Restored Imperial Standard Pound Avoirdupois*, is constructed of Platinum, the Form being that of a *Cylinder* nearly 1·35 inch in height, and 1·15 inch in Diameter, marked P.S., 1844, 1 lb.

DIVISION 1.—AVOIRDUPOIS WEIGHT.

$27\frac{11}{32}$	Grains	= 1	Drachm......	=	$27\frac{11}{32}$	grains
16	Drachms	= 1	Ounce	=	$437\frac{1}{2}$	"
16	Ounces	= 1	Pound (lb.)	=	7000	"
14	Pounds	= 1	Stone.			
28	Pounds	= 1	Quarter (qr.)			
4	Quarters	= 1	Hundred weight (cwt.)			
20	Cwt.	= 1	Ton			

This weight is used in almost all commercial transactions, and in all the common dealings of life.

By an act of parliament passed the 5th of October, 1831, and which came into effect on the 1st of January, 1832, it is directed that all coals, cinders, and culm, sold from and out of any ship or vessel in the port of London; or at any place within the cities of London and Westminster, or within the distance of 25 miles from the General Post Office, in the city of London, should be sold by weight and not by measure.

Coals sold in any quantity exceeding 500 lbs., are to be delivered to the purchaser in sacks containing either 112 lbs. or 224 lbs. net; 10 such sacks, or 2240 lbs., make a ton, equal to 20 cwt.; $25\frac{1}{2}$ cwt. are equivalent to 1 chaldron. A barge load, or keel, is 21 tons, 4 cwt.; and a collier, or ship load, about 20 such keels, or 424 tons.

By an act of parliament, which came into effect on the 29th of September, 1822, bread must be sold by the pound avoirdupois, and bakers are prohibited from selling by the peck-loaf with its subdivisions.

Flour is sold nominally by measure, but actually by weight, at 7 lbs. avoirdupois to a gallon, 14 lbs. to a peck, &c.

By a late act of parliament, the legal stone is, in all cases, to consist of 14 lbs. avoirdupois; 8 such stone 1 cwt.; 20 cwt. 1 ton.

V.—Measures of Space.

A *Circle* contains 360 degrees; a *Degree* 60 minutes; a *Minute*, 60 seconds, &c.; consequently a *Semi-circle* contains 180 degrees; a *Quadrant*, 90 degrees; a *Sextant* 60 degrees; and an *Octant*, 45 degrees; a *right angle* contains, or is measured by 90 degrees, and two right

angles by 180 degrees. The *circumference* of a circle is nearly $3\frac{1}{7}$ times its diameter, or more accurately 3·1416 times; in other words, this number is the *circumference* of a circle, whose *diameter* is unity; consequently the *diameter* of a circle is nearly 7·22, or more accurately ·31831 of its circumference. In France the *circle* is frequently divided into 400 degrees, a degree into 100 minutes, and a minute into 100 seconds, &c. The latter is called the *centesimal* system, and the former the *sexagesimal;* consequently, 1 centesimal degree contains 54 sexagesimal minutes; 1 centesimal minute, 32·4 sexagesimal seconds; 1 centesimal second, ·324 of a sexagesimal second; and also 1 sexagesimal degree contains $1\frac{1}{9}$ centesimal degree; 1 sexagesimal minute, 1·85185 centesimal minutes; and 1 sexagesimal second, 3·08641 centesimal seconds. A mean *sexagesimal* degree of the terrestrial meridian measures 69·045 imperial miles.

ANGULAR MEASURE, OR DIVISIONS OF THE CIRCLE.

60 Seconds..................	=	1 Minute.
60 Minutes	=	1 Degree.
30 Degrees	=	1 Sign.
90 Degrees	=	1 Quadrant.
4 Quadrants	=	1 Circle.
360 Degrees, or 12 Signs.	=	1 Circumference or circle.

VI.—Measures of Time and Motion.

A *Mean Solar Day* is the mean apparent time of one revolution of the earth on its axis; and is divided into 24 hours; an hour into 60 minutes; and a minute into 60 seconds, &c.; hence the mean daily apparent motion of the sun is 15 degrees per hour, or 1 degree in 4 minutes of time. A *Sidereal Day* is the real and invariable period of the diurnal rotation, and contains 23 hours, 56 minutes, $4\frac{1}{10}$ seconds of mean solar time. A *Tropical Year* is the period of one revolution of the earth in its orbit, and contains 335 days, 5 hours, 48 minutes. 49·19 seconds of mean solar time. The seconds pendulum makes 86,400 vibrations in a mean solar day at the same place on the earth's surface.

DECIMALS OF A FOOT AND A SHILLING.

1	=	·083333
2	=	·166666
3	=	·25
4	=	·333333
5	=	·416666
6	=	·5
7	=	·583333
8	=	·666666
9	=	·75
10	=	·833333
11	=	·916666

To find the area of a circle, multiply Diameter by itself, and again by 7854.

To find the circumference, multiply 3·1416 by the diameter.

Weight of Coal in Tons per Acre, from 1 inch thick to 12 feet 11 inches.

	Inches.	1	2	3	4	5	6	7	8	9	10	11
Ft.	Tons.	126·60	253·20	379·81	506·41	633·02	759·62	886·23	1012·03	1139·44	1266·04	1392·64
1	1519·25	1645·85	1772·45	1899·06	2025·66	2152·27	2278·87	2405 48	2532·08	2658·69	2785·29	2911·89
2	3038·50	3165·10	3291·70	3418·31	3544·91	3671·52	3798·12	3924·73	4051·33	4177·94	4304·54	4431·14
3	4557·75	4684·35	4810·95	4937·56	5064·16	5190·77	5317 37	5443·98	5570·58	5697·19	5823·79	5950·39
4	6077·00	6203·60	6330·20	6456·81	6583·41	6710·02	6836·62	6963·23	7089·83	7216·44	7343·04	7469·64
5	7596·25	7722·85	7849·45	7976·06	8102·66	8229·27	8355·87	8482·48	8609·08	8735·69	8862·29	8988·89
6	9115·51	9242·11	9368·71	9495·32	9621·92	9748·53	9875·13	10001·74	10128·34	10254·95	10381·55	10508·15
7	10634·76	10761·36	10887·96	11014·57	11141·17	11267·78	11394·38	11520·99	11647·59	11774·20	11900·80	12027·40
8	12154·01	12280·61	12407·21	12533·82	12660·42	12787·03	12913·63	13040·24	13166·84	13293·45	13420·05	13546·65
9	13673·27	13799·87	13926·47	14053·08	14179·68	14306·29	14432·89	14559·50	14686·10	14812·71	14939·31	15065·91
10	15192·52	15319·12	15445·72	15572·33	15698·93	15825·54	15952·14	16078·75	16205·35	16331·96	16458·56	16585·16
11	16711·77	16838 37	16964·97	17091·58	17218·18	17344·79	17471·39	17598·00	17724·60	17851·21	17977·81	18104·41
12	18231·02	18357·62	18484·22	18610·83	18737·43	18864·04	18990·64	19117·25	19243·85	19370·46	19497·06	19623·66

Calculated for a Specific Gravity of 1·25.

N.B.—Six or seven of the following valuable Tables and Calculations are by Mr. Fairley, Colliery Manager.

WEIGHT OF COAL UNDER DIFFERENT CIRCUMSTANCES.

Specific Gravity.		Weight of coal per acre per inch thick in tons.
1·10	....	111·411
1·15	....	116·475
1·20	....	121·540
1·25	....	121·604
1·30	....	131·668
1·35	....	136·732
1·40	....	141·796
1·45	....	146·860
1·50	....	151·925

TABLE SHOWING PRICE PER TON, WHEN THE COAL IS RECKONED AT SO MUCH FOOTAGE TO THE ACRE (CHESHIRE MEASURE). FROM £20 TO £200 PER FOOT PER ACRE.

32414·28.*

Per Acre per Foot. £		Per Ton. d.	Per Acre per Foot. £		Per Ton. d.
20	....	1·49	115	....	8·58
25	....	1·86	120	....	8·96
30	....	2·24	125	....	9·33
35	....	2·61	130	....	9·70
40	....	2·98	135	....	10·08
45	....	3·36	140	....	10·45
50	....	3·73	145	....	10·82
55	....	4·11	150	....	11·20
60	....	4·48	155	....	11·57
65	....	4·85	160	....	11·94
70	....	5·22	165	....	12·32
75	....	5·60	170	....	12·69
80	....	5·97	175	....	13·06
85	....	6·34	180	....	13·44
90	....	6·72	185	....	13·81
95	....	7·09	190	....	14·18
100	....	7·46	195	....	14·56
105	....	7·84	200	....	14·93
110	....	8·21	205	....	15·30

* The number of tons in a Cheshire acre of coal, 12 inches thick.

TABLE SHOWING QUANTITY OF WATER, IN IMPERIAL GALLONS, DELIVERED BY A PUMP AT EACH STROKE OF THE ENGINE.

Dia. of Pump in inches.	Length of Stroke.					
	1ft. 6in.	2ft. 0in.	2ft 6in.	3ft. 0in.	3ft. 6in.	4ft. 0in.
3	0·46	0·61	0·76	0·91	1·06	1·22
4	0·82	1.09	1·36	1·63	1·90	2·17
5	1·27	1·70	2·12	2·55	2·97	3·40
6	1·84	2·44	3·05	3·67	4·28	4·89
7	2·50	3·33	4·16	4·99	5·82	6·66
8	3·26	4·35	5·43	6·52	7·61	8·70
9	4·13	5·50	6·88	8·26	9·63	11·01
10	5·10	6·80	8·50	10·20	11·90	13·60
11	6·17	8·22	10·27	12·33	14·39	16·45
12	7·34	9·79	12·23	14·68	17·13	19·58
13	8·61	11·49	14·36	17·23	20·10	22·98
14	9·99	13·32	16·65	19·98	23·31	26·65
15	11·47	15·29	19·11	22·94	26·76	30·59
16	13·05	17·40	21·76	26·11	30 46	34·81
17	14·73	19·65	24·56	29·47	34 38	39·30
18	16·52	22·02	27·53	33·04	38·54	44·05
19	18·40	24·54	30·67	36·81	42·94	49·08
20	20·39	27·19	33·99	40·79	47·59	54·39
21	22·48	29·98	37·47	44·97	52·46	59·96
22	24·68	32·90	41·13	49·36	57·59	65·81
23	26·97	35·96	44·95	53·94	62·93	71·93
24	29·37	39·16	48·95	58·74	68·53	78·32
25	31·87	42·49	53·11	63·73	74·35	84·98
26	34·47	45·96	57·45	68·94	80·43	91·92
27	37·17	49·56	61·95	74·34	86·73	99·13
28	39·97	53·30	66·62	79·95	93·28	106·61
29	42·88	57·18	71·47	85·77	100·06	114·36
30	45·89	61·19	76·48	91·78	107·08	122·38
31	49·00	65·33	81·66	98·00	114·33	130·67
32	52·21	69·62	87·02	104·43	121·83	139·24
33	55·53	74·04	92·55	111·06	129·57	148·08
34	58·94	78·59	98·24	117·89	137·54	157·19
35	62·46	83·28	104·10	124·93	145·75	166·57
36	66·08	88·11	110·10	132·16	154·19	176·22

TABLE SHOWING QUANTITY OF WATER, IN IMPERIAL GALLONS, DELIVERED BY A PUMP AT EACH STROKE OF THE ENGINE (CONTINUED).

Dia. of Pump in inches.	Length of Stroke.					
	4ft. 6in.	5ft. 0in.	5ft. 6in.	6ft. 0in.	6ft. 6in.	7ft. 0in.
3	1·37	1·52	1·68	1·83	1·97	2·13
4	2·44	2·72	2·99	3·26	3·53	3·80
5	3·82	4·25	4·67	5·10	5·52	5·95
6	5·50	6·11	6·73	7·34	7·95	8·56
7	7·49	8·32	9·16	9·99	10·81	11·65
8	9·78	10·87	11·96	13·05	14·13	15·22
9	12·38	13·76	15·14	16·52	17·89	19·27
10	15·30	17·00	18·70	20·40	22·10	23·80
11	18·50	20·55	22·62	24·67	26·72	28·78
12	22·02	24·47	26·92	29·37	31·81	34·26
13	25·85	28·72	31·59	34·47	37·33	40·21
14	29·97	33·30	36·64	39·97	43·29	46·63
15	34·41	38·23	42·06	45·89	49·70	53·53
16	39·16	43·51	47·86	52·22	56·57	60·92
17	44·21	49·12	54·03	58·95	63·85	68·77
18	49·55	55·06	60·57	66·08	71·58	77·09
19	55·21	61·35	67·48	73·62	79·75	85·89
20	61·18	67·98	74·78	81·58	88·38	95·18
21	67·45	74·95	82·44	89·94	97·43	104·93
22	74·03	82·26	90·49	98·72	106·95	115·17
23	80·91	89·90	98·90	107·89	116·87	125·87
24	88·11	97·90	107·69	117·48	127·27	137·06
25	95·60	106·22	116·85	127·47	138·08	148·71
26	103·41	114 90	126·39	137·88	149·37	160·86
27	111·51	123·90	136·30	148·69	161·07	173·47
28	119·93	133·25	146·58	159·91	173·23	186·56
29	128·65	142 95	157·24	171·54	185·83	200·13
30	137·67	152·97	168·27	183·57	198·86	214·16
31	147·00	163·33	179·67	196·01	212·33	228·67
32	156·64	174·05	191·45	208·86	226·26	243·67
33	166·59	185·10	203·61	222·12	240·63	259·14
34	176·83	196·48	216·13	235·79	255·43	275·08
35	187·39	208·21	229·03	249·86	270·68	291·50
36	198·24	220·27	242·30	264·33	286·35	308·38

TABLE SHOWING QUANTITY OF WATER, IN IMPERIAL GALLONS, DELIVERED BY A PUMP AT EACH STROKE OF THE ENGINE (CONTINUED).

Dia. of Pump in inches	Length of Stroke. 7ft. 6in.	8ft. 0in.	8ft. 6in.	9ft. 0in.	9ft. 6in.	10ft. 0in.
3	2·28	2·45	2·59	2·74	2·89	3·06
4	4·07	4·35	4·61	4·89	5·16	5·44
5	6·37	6·80	7·22	7·65	8·07	8·50
6	9·17	9·79	10·39	11·00	11·61	12·23
7	12·48	13·32	14·15	14·98	15·81	16·65
8	16·31	17·40	18·48	19·57	20·65	21·75
9	20·64	22·03	23·39	24·77	26·14	27·53
10	25·50	27·20	28·90	30·60	32·30	34·00
11	30·84	32·90	34·95	37·00	39·05	41·12
12	36·71	39·16	41·60	44·05	46·49	48·95
13	43·08	45·96	48·83	51·70	54·57	57·45
14	49·96	53·30	56·62	59·95	63·27	66·62
15	57·35	61·19	65·00	68·82	72·64	76·48
16	65·27	69·62	73·97	78·32	82·67	87·02
17	73·68	78·60	83·51	88·42	93·33	98·25
18	82·59	88·11	93·60	99·11	104·61	110·13
19	92·02	98·17	104·29	110·43	116·56	122·71
20	101·98	108·78	115·57	122·37	129·16	135·97
21	112·42	119·93	127·41	134·91	142·40	149·91
22	123·40	131·63	139·84	148·07	156·29	164·53
23	134·86	143·86	152·84	161·83	170·81	179·82
24	146·85	156·65	166·43	176·22	186·01	195·81
25	159·33	169·97	180·58	191·22	201·82	212·46
26	172·35	183·85	195·33	206·82	218·31	229·81
27	185·86	198·26	210·64	223·03	235·41	247·82
28	199·89	213·22	226·54	239·86	253·18	266·52
29	214·42	228·72	243·01	257·31	271·16	285·90
30	229·46	244·76	260·05	275·35	290·64	305·95
31	245·00	261·35	277·67	294·00	310·33	326·68
32	261·07	278·48	295·88	313·29	330·69	348·10
33	277·65	296·16	314·67	333·18	351·69	370·20
34	294·73	314·39	334·02	353·67	373·31	392·98
35	312·32	333·15	353·96	374·78	395·60	416·43
36	330·41	352·44	374·46	396·49	418·51	440·55

TABLE OF INCLINE MEASURE.

Showing the comparative lengths of the three legs of a right-angled triangle, likewise the gravity due to incline, and the number of square yards in an acre, &c., for every degree of the quadrant, for various practical uses, as per explanations following:—

No of Degrees. 1.	Inclination per Yard in Inches. 2.	One in 3.	Horizontal Measure, Hypothenuse being 1 4.	Vertical Measure, Hypothenuse being 1 5	Deduct links per Chain. 6.	Gravity due to Incline per ton, in lbs. 7.	Square Yards per Acre. 8.	No. of Degree. 9.
1	0·63	57·29	·99985	·01745	0·01	39·08	4840·72	1
2	1·26	28·63	·99939	·03490	0·06	78·18	4842·95	2
3	1·88	19·09	·99863	·05234	0·14	117·24	4846·63	3
4	2·51	14·29	·99756	·06976	0·24	156·26	4851·83	4
5	3·15	11·42	·99619	·08716	0·38	195·62	4858·51	5
6	3·78	9·51	·99452	·10453	0·55	234·14	4866·66	6
7	4·42	8·14	·99255	·12187	0·74	272·98	4876·32	7
8	5·06	7·11	·99027	·13917	0·97	311·74	4887·55	8
9	5·70	6·31	·98769	·15643	1·23	350·40	4900·32	9
10	6·34	5·67	·98481	·17365	1·52	388·97	4914·65	10
11	6·99	5·14	·98163	·19081	1·84	427·41	4930·57	11
12	7·65	4·70	·97815	·20791	2·19	465·71	4948·11	12
13	8·31	4·33	·97437	·22495	2·56	503·88	4967·31	13
14	8·97	4·01	·97030	·24192	2.97	541·90	4988·14	14
15	9·64	3·73	·96593	·25882	3·40	579·75	5010·71	15
16	10·32	3·48	·96126	·27564	3·87	617·43	5035·05	16
17	11·C0	3·27	·95630	·29237	4·37	654·90	5061·17	17
18	11·69	3·07	·95106	·30902	4·89	692·20	5089·05	18
19	12·39	2·90	·94552	·32557	5·45	729·27	5118·87	19
20	13·10	2·74	·93969	·34202	6·03	766·12	5150·63	20
21	13·82	2·60	·93358	·35837	6·64	802·74	5184·34	21
22	14·54	2·47	·92718	·37461	7·28	839·12	5220·12	22
23	15·27	2·35	·92050	·39073	7·95	875·23	5258·01	23
24	16·02	2·24	·91355	·40674	8·65	911·09	5298·01	24
25	16·78	2·14	·90631	·42262	9·37	946·66	5340·33	25
26	17·56	2·05	·89879	·43837	10·12	981·94	5385·01	26
27	18·34	1·96	·89101	·45399	10·90	1016·93	5132·03	27
28	19·14	1·88	·88295	·46947	11·71	1051·61	5481·62	28
29	19·95	1·80	·87462	·48481	12·54	1085·97	5533·83	29
30	20·78	1·73	·86602	·5	13·40	1120·00	5588·78	30
31	21·62	1·66	·85717	·51504	14·28	1153·68	5646·48	31
32	22·49	1·60	·84805	·52992	15·19	1187·02	5707·21	32
33	23·37	1·54	·83867	·54464	16·13	1219·99	5771·04	33
34	24·28	1·48	·82904	·55919	17·10	1252·58	5838·07	34
35	25·20	1·42	·81915	·57358	18·08	1284·81	5908·56	35
36	26·15	1·37	·80902	·58778	19·10	1316·62	5982·54	36
37	27·12	1·32	·79864	·60181	20·14	1348·05	6060·30	37
38	28·12	1·28	·78801	·61566	21·20	1379·07	6142·05	38
39	29·14	1·23	·77715	·62932	22·28	1409·67	6228·01	39
40	30·21	1·19	·76604	·64279	23·40	1439·84	6318·20	40
41	31·29	1·15	·75471	·65606	24·53	1469·57	6413·05	41
42	32·41	1·11	·74314	·66913	25·69	1498·85	6512·90	42
43	33·56	1·07	·73135	·68200	26·86	1527·68	6617·89	43

TABLE OF INCLINED MEASURE (continued).

No. of Degree. 1.	Inclination per Yard in Inches. 2.	One in 3.	Horizontal Measure, Hypothenuse being 1. 4.	Vertical Measure, Hypothenuse being 1. 5.	Deduct links per Chain. 6.	Gravity due to Incline per ton in lbs. 7.	Square Yards per Acre. 8.	No. of Degree. 9.
44	34·76	1·03	·71934	·69466	28·07	1556·03	6728·38	44
45	36·00	1·00	·70711	·79711	29·29	1583·92	6844·76	45
46	37·27	·96	·69466	·71934	30·53	1611·32	6967·43	46
47	38·60	·93	·68200	·73135	31·80	1638·22	7096·77	47
48	39·98	·90	·66913	·74314	33·09	1664·63	7233·27	48
49	41·41	·87	·65606	·75471	34·39	1690·55	7377·37	49
50	42·90	·84	·64279	·76604	35·72	1715·92	7529·67	50
51	44·46	·81	·62932	·77715	37·07	1740·81		51
52	46·07	·75	·61566	·78801	38·43	1765·14		52
53	47·77	·73	·60181	·79864	39·82	1788·95		53
54	49·54	·70	·58778	·80902	41·22	1812·20		54
55	51·41	·67	·57358	·81915	42·64	1834·89		55
56	53·36	·65	·55919	·82904	44·08	1857·04		56
57	55·44	·62	·54464	·83867	45·54	1878·62		57
58	57·61	·62	·52992	·84805	47·01	1899·63		58
59	59·92	·60	·51504	·85717	48·50	1920·06		59
60	62·35	·58	·5	·86602	50·00	1939·88		60
61	64·94	·55	·48481	·87462	51·52	1959·14		61
62	67·69	·53	·46947	·88295	53·05	1977·80		62
63	70·65	·51	·45399	·89101	54·60	1995·86		63
64	73·80	·49	·43837	·89879	56·16	2013·28		64
65	77·20	·47	·42262	·90631	57·74	2030·13		65
66	80·86	·45	·40674	·91355	59·33	2046·35		66
67	84·81	·42	·39073	·92050	60·93	2061·92		67
68	89·10	·40	·37461	·92718	62·54	2076·88		68
69	93·77	·38	·35837	·93358	64·16	2091·21		69
70	98·91	·36	·34202	·93969	65·80	2104·90		70
71	104·53	·34	·32557	·94552	67·44	2117·96		71
72	110·80	·32	·30902	·95106	69·10	2130·37		72
73	117·73	·31	·29237	·95630	70·76	2140·11		73
74	125·56	·29	·27564	·96126	72·44	2153·22		74
75	134·37	·27	·25882	·96593	74·12	2163·68		75
76	144·40	·25	·24192	·97030	75·81	2173·47		76
77	155·90	·23	·22495	·97437	77·50	2182·58		77
78	169·36	·21	·20791	·97815	79·21	2191·05		78
79	185·20	·19	·19081	·98163	80·92	2198·85		79
80	204·10	·18	·17365	·98481	82·63	2205·97		80
81	227·34	·16	·15643	·98769	84·36	2212·42		81
82	256·11	·14	·13917	·99027	86·08	2218·20		82
83	293·13	·12	·12187	·99253	87·81	2223·26		83
84	342·60	·10	·10453	·99452	89·55	2227·72		84
85	411·27	·09	·08716	·99619	91·28	2231·46		85
86	514·52	·07	·06976	·99756	93·02	2234·53		86
87			·05234	·99863	94·77	2236·93		87
88			·03490	·99939	96·51	2238·63		88
89			·01745	·99985	98 25	2239·66		89

It is obviously unnecessary to give this above (about) 80 degrees.

REMARKS ON THE CONSTRUCTION AND APPLICATION OF THE FOREGOING TABLE.

COLUMN 1.—This is the amount of the angle which inclined planes make with the horizon, and is found sometimes with the compass-cover and a small plummet, more correctly with a quadrant attached to the compass for the purpose, but more accurately by a theodolite.

COLUMN 2 gives the expression of the amount of elevation in phraseology more familiar to many colliery agents than "degrees," for, when speaking of the amount of the rise of underground roads, they generally say they rise so much per yard.

COLUMN 3.—This is only another way of expressing the amount of the gradient, and is obtained by dividing the horizontal measure by the vertical rise.

COLUMN 4.—The figures given in this column show the length of the cosine, radius being unity; or, in other words, the length of the base of a right-angled triangle, the hypothenuse being one. Therefore, in order to obtain the length of the horizontal measure, when the hypothenuse and angle have been obtained, say.

As 1 : cosine : : hypothenuse : base; or multiply the hypothenusal measure by the figures in this column, and the result will be the horizontal measure.

EXAMPLE: I took a sight up an incline rising 35 deg., and the distance on the slant was 870 links; what is the horizontal measure—what is the proper distance to be plotted?

Opposite 35 in the fourth column I find ·81915; this, multiplied by 870 = 712·66, or 712¾ links nearly.

The same result may be obtained by deducting the proper number of links per chain as given in column 6.

COLUMN 5.—The figures in this column show the length of the sine, radius being one, or the length of the perpendicular of a right-angled triangle, hypothenuse being unity; therefore to ascertain the amount of rise on an incline, the elevation and slant distance being given, say,

As 1 : sine : : hypothenuse : perpendicular; or multiply the slant measure by the figures in this column opposite the number of degrees.

EXAMPLE: What is the vertical rise of an incline whose angle is 36 deg., and slant distance 400 links?

$$400 \times \cdot58778 = 235\cdot112 \text{ links,}$$
$$\text{or, } 235\cdot112 \times 7\cdot92 = 155\text{ft. } 2\text{in.}$$

For an explanation of the manner of forming a table of natural sines, cosines, &c., see any treatise on plane trigonometry.

It may be asked why we have extended the table beyond 45 deg., when it is so well understood that the cosines of 46 deg., 47 deg., 48 deg., &c., are always the same as the sines of 44 deg., 43 deg., 42 deg., &c., respectively. We think that by doing so we simplify matters, and besides it is necessary for showing the figures in columns 2, 3, 6, 7, and 8.

COLUMN 6.—The number of links to be deducted in a chain, given in this column, has been found thus:—

$$100 - \frac{\text{Cosine} \times 100;}{1}$$

and the reason will be apparent from what has already been said.

COLUMN 7.—A body on an inclined plane will be supported by a weight which bears the same proportion to it that the height does to the length of the plane. Thus, at an angle of 28 deg. we have the length and height of the plane in the proportion of 1 to ·46947, therefore the weight that would support, say 2,240lbs., at this angle would be

$$\text{As } 1 : \cdot 46947 :: 2240 : 1051\cdot 61.$$

This is what we have called the "gravity due to incline" in the table. The weight shown has been obtained by multiplying the number of pounds in a ton by the sine of the different angles. These figures will be found of some use in the case of slants, where, for instance, coal is pulled up an inclined plane by means of a stationary engine and a rope.

EXAMPLE: The weight of the tubs, coals, rope, &c., which is pulled up a slant whose angle is 26 deg., amounts to 70 cwt.: to how much weight is this equivalent pulled up vertically, or what is the working load of the rope, independent of friction?

70 cwt. = 7,840lbs.

Opposite angle 26 deg., in column 7, we find 981·94.

Then as 2240 : 981·94 :: 7840 : 3437 lbs., or 30 cwt., 2 qrs., 21 lbs. Then, by referring to the "Table of the Weight and Strength of Ropes," we shall ascertain the size of rope required for this work according to the makers' rule. (Due allowance must be made for friction, &c.)

COLUMN 8.—Everybody knows that there are 4,840 square yards in a statute acre; but in the case of property lying obliquely, which is not unfrequently so with coal seams, there is plainly an increase of superficial measure under a given area in proportion to the angle of elevation, so that the number of square yards in an acre of coal depends on the declivity.

The figures in this column show the ratio of increase from 1 to 50 deg., and are obtained by the following formula:—

$$\frac{1 \times 4840}{\text{cosine.}}$$

APPLICATION:—A colliery proprietor desires to know how many cubic yards of coal there are under twelve acres of land in a seam 6ft. thick, measured at right angles to the line of dip, the amount of which is uniformly 30 deg., which is supposed to be lying evenly and uninterruptedly throughout, and the whole of which will be won by a level at the lowest boundary?

The number of square yards in an acre per the table is 5588·78: thickness of seams two yards.

Then 5588·78 x 2 = 11177·56 cubic contents in yards per acre, and 11177·56 x 12 = 134130·72 total contents.

This result, we are aware, may be arrived at otherwise, namely, by measuring the thickness of the seam vertically.

This would be $\dfrac{6}{\cdot 86602} = 6\cdot 9282$ ft., and $\dfrac{4840 \times 6\cdot 9282}{3} = 11177\cdot 50$ yards per acre, same as above very nearly.

TABLE SHOWING THE DIFFERENCE BETWEEN TRUE AND APPARENT LEVELS, IN FEET, CALCULATED BY THE FOLLOWING FORMULA :—

$$\frac{\text{Distance}^2}{\text{Diameter of earth.}}$$

The diameter of the earth, 7912 miles : $\frac{1}{7}$th deducted for refraction.

Distance in Chains.	Difference for Curvature.	Corrected for Refraction.	Distance in Miles.	Difference for Curvature.	Corrected for Refraction.
1	·000104	·000089	$0\frac{1}{4}$	0·042	0·036
2	·000417	·000358	$0\frac{1}{2}$	0·167	0·142
3	·000938	·000804	$0\frac{3}{4}$	0·375	0·322
4	·001668	·001430	1	0·667	0·571
5	·002605	·002233	2	2·667	2·285
6	·003752	·003216	3	6·000	5·150
7	·005107	·004378	4	10·675	9·150
8	·006670	·005717	5	16·675	14·292
9	·008442	·007236	6	24·008	20·578
10	·010422	·008933	7	32·683	28·014
11	·012610	·010809	8	42·692	36·593
12	·015007	·012863	9	54·025	46·307
13	·017613	·015097	10	66·700	57·171
14	·020427	·017509	11	80·708	69·178
15	·023450	·020100	12	96·050	82·329
16	·026780	·022869	13	112·717	96·615
17	·030120	·025817	14	130·733	112·057
18	·033623	·028943	15	150·075	128·638
19	·037567	·032248	16	170·750	146·357
20	·041687	·035732	17	192·767	165·229
21	·045960	·039394	18	216·108	185·235
22	·050442	·043236	19	240·783	206·385
23	·055132	·047259	20	266·800	228·686
24	·060031	·051455	Feet.		
25	·065137	·055832	500	0·00598	0·00513
26	·070452	·060388	1000	0·02398	0·02050
27	·075975	·065121	2000	0·09570	0·08206
28	·081708	·070036	3000	0·21533	0·18457
29	·087648	·075127	4000	0·38281	0·32812
30	·093798	·080399	5000	0·59814	0·51269

TABLE OF RAILWAY GRADIENTS, OR INCLINED PLANES.

Reduced to one in ten.

Feet per mile.	Inclination.	Inches per chain of 66 feet.
1	1 in 5280	0·15
2	1 in 2640	0·30
3	1 in 1760	0·45
4	1 in 1320	0·60
5	1 in 1056	0·75
6	1 in 880	0·90
7	1 in 754·2	1·05
8	1 in 660	1·20
9	1 in 586·6	1·35
10	1 in 528	1·50
11	1 in 480	1·65
12	1 in 440	1·80
13	1 in 406·1	1·95
14	1 in 377·1	2·10
15	1 in 352	2·25
16	1 in 330	2·40
17	1 in 310·6	2·55
18	1 in 293·3	2·70
19	1 in 277·9	2·85
20	1 in 264	3·00
21	1 in 251·4	3·15
22	1 in 240·4	3·30
23	1 in 229·5	3·45
24	1 in 220	3·60
25	1 in 211·2	3·75
26	1 in 203·1	3·99
27	1 in 195·5	4·05
28	1 in 138·6	4·20
29	1 in 182·1	4·35
30	1 in 176	4·50
31	1 in 170·3	4·65
32	1 in 165	4·80
33	1 in 160	4·95
34	1 in 155·3	5·10
35	1 in 150·8	5·25
36	1 in 146·6	5·40
37	1 in 142·7	5·55
38	1 in 138·9	5·70
39	1 in 135·4	5·85
40	1 in 132	6·00
41	1 in 128	6·15
42	1 in 125·7	6·30
43	1 in 122·8	6·45
44	1 in 120	6·60
45	1 in 117·3	6·75
46	1 in 114·8	6·90
47	1 in 112·3	7·05
48	1 in 110	7·28
49	1 in 107·7	7·35
50	1 in 105·6	7·50
51	1 in 103·5	7·65
52	1 in 101·5	7·80
53	1 in 99·6	7·95
54	1 in 97·8	8·10
55	1 in 96	8·25
56	1 in 94·3	8·40
57	1 in 92·6	8·55
58	1 in 91	8·70
59	1 in 89·5	8·85
60	1 in 88	9·00
61	1 in 86·5	9·15
62	1 in 85·1	9·35
63	1 in 83·8	9·40
64	1 in 82·5	9·65
65	1 in 81·2	9·70
66	1 in 80	9·90
67	1 in 78·8	10·5
68	1 in 77·6	10·20
69	1 in 76·5	10·35
70	1 in 75·4	10·50
71	1 in 74·2	10·65
72	1 in 73·3	10·80
73	1 in 72·3	10·95
74	1 in 71·3	11·10
75	1 in 70·4	11·25
76	1 in 69·4	11·41
77	1 in 68·5	11·56
78	1 in 67·7	11·70
79	1 in 66·8	11·85
80	1 in 66	12·
81	1 in 65·1	12·16
82	1 in 64·4	12·30

TABLE OF RAILWAY GRADIENTS, OR INCLINED PLANES.

(CONTINUED.)

Feet per mile.	Inclination.	Inches per chain of 66 feet.	Feet per mile.	Inclination	Inches per chain of 66 feet.
83	1 in 63·6	12·45	240	1 in 22	36·
84	1 in 62·8	12·60	250	1 in 21·12	37·5
85	1 in 62·1	12·75	260	1 in 20·3	39·
86	1 in 61·4	12·90	270	1 in 19·55	40·5
87	1 in 60·6	13·5	280	1 in 18·85	42·
88	1 in 60	13·20	290	1 in 18	43·5
89	1 in 59·3	13·35	300	1 in 17·6	45·
90	1 in 58·6	13·50	310	1 in 17·3	46·5
91	1 in 58	13·65	320	1 in 16·5	48·
92	1 in 57·4	13·80	330	1 in 16	49·5
93	1 in 56·7	13·95	340	1 in 15·52	51·
94	1 in 56·1	14·10	350	1 in 15	52·5
95	1 in 55·5	14·26	360	1 in 14·66	54·
96	1 in 55	14·4	370	1 in 14·27	55·5
97	1 in 54·4	14·55	380	1 in 13·89	57·
98	1 in 53·8	14·7	390	1 in 13·53	58·5
99	1 in 53·3	14·85	400	1 in 13·2	60·
100	1 in 52·8	15·	410	1 in 12·87	61·5
110	1 in 48	16·5	420	1 in 12·59	63·
120	1 in 44	18·	430	1 in 12·27	64·5
130	1 in 40·61	19·5	440	1 in 12	66·
140	1 in 37·7	21·	450	1 in 11·75	67·5
150	1 in 35·2	22·5	460	1 in 11·47	69·
160	1 in 33	24·	470	1 in 11·23	70·5
170	1 in 31·05	25·5	480	1 in 11	72·
180	1 in 29·33	27·	490	1 in 10·77	73·5
190	1 in 27·78	28·5	500	1 in 10·56	75·
200	1 in 26·4	30·	510	1 in 10·35	76·5
210	1 in 25·14	31·5	520	1 in 10·15	78·
220	1 in 24	33·	528	1 in 10	79·2
230	1 in 22·95	33·5			

TABLES SHOWING THE TENACITY OF WROUGHT IRON AND STEEL.

Material.	Tenacity in lbs. per square inch. Lengthwise.	Crosswise.	Authority.
Wire—very strong, charcoal	114,000	...	Morin
Wire—average	86,000	...	Telford
Wire—weak	71,000	...	Morin

TABLES SHOWING THE TENACITY OF WROUGHT IRON AND STEEL (CONTINUED).

Material.	Tenacity in lbs. per square inch. Lengthwise.	Crosswise.	Authority.
Yorkshire (Low Moor)	64,200	52,490	Fairbairn
" " from	66,390	....	Kirkaldy
" " to	60,075	....	
Yorkshire (Lower Moor) and Staffordshire rivet iron	59,750	....	Fairbairn
Charcoal bar	63,630	....	do.
Staffordshire bar from	62,231	....	Kirkaldy
to	56,715	....	
Yorkshire bridge iron	49,930	43,940	Fairbairn
Staffordshire bridge iron	47,600	44,385	do.
Lanarkshire bar from	64,795	....	Kirkaldy
to	51,327	....	
Lancashire bar from	60,110	....	do.
to	53,773	....	
Swedish bar from	48,933	....	do.
to	41,251	....	
Russian bar from	59,096	....	do.
to	49,564	....	
Bushelled iron from turnings	55,878	....	do.
Hammered scrap	53,420	....	do.
Angle iron from various districts— from	61,250	....	do.
to	50,056	....	
Bessemer's iron, cast ingot	41,242	....	Wilmot
Bessemer's iron, hammered or rolled.	72,643	....	do.
Bessemer's iron, boiler plate	68,319	....	do.
Yorkshire plates from	58,487	55,033	Kirkaldy
to	52,000	46,221	
Staffordshire plates from	56,996	52,251	do.
to	46,404	44,764	
Staffordshire plates, best-best charcoal	45,010	41,420	Fairbairn
Staffordshire plates, best-best from	59,820	54,820	do.
to	49,945	46,470	
Staffordshire plates, best	61,280	53,820	do.
Staffordshire plates, common	50,820	52,825	do.
Lancashire plates	48,865	45,015	do.
Lanarkshire plates from	53,849	48,848	Kirkaldy
to	43,433	39,544	

TABLE SHOWING THE TENACITY OF WROUGHT IRON AND STEEL (CONTINUED).

Material.	Tenacity in lbs. per square inch. Lengthwise.		Crosswise.	Authority.
Durham plates	51,245	...	46,712	Kirkaldy.
Cast steel bars rolled & forged...from	132,909	...	....	do.
to	92,015	...	....	
Cast steel bars rolled and forged	130,000	...	....	Rennie.
Blistered steel bars, rolled & forged	104,290	...	....	Kirkaldy.
Shear steel bars, rolled and forged	118,468	...	....	do.
Bessemer's steel bars, rolled & forged	111,460	...	....	do.
Bessemer's steel bars, cast ingots	63,024	...	....	Wilmot.
Bessemer's steel bars, hammered or rolled	152,912	...	....	do.
Spring steel bars, hammered or rolled	72,529	...	....	Kirkaldy.
Homogeneous metal bars, rolled	90,647	...	....	do.
Homogeneous metal bars, rolled	93,000	...	....	Fairbairn.
Homogeneous metal bars, forged	89,724	...	....	Kirkaldy.
Puddled steel bars, rolled and forged from	71,484	...	....	do.
to	62,768	...	....	
Puddled steel bars, rolled and forged	90,000	...	....	Fairbairn.
Puddled steel bars, rolled and forged	94,752	...	....	Mallet.
Mushet's gun metal	103,400	...	....	Fairbairn.
Cast steel plates...from	96,289	...	97,308	Kirkaldy.
to	75,594	...	69,082	
Cast steel plates...hard	102,900	...	....	Fairbairn.
soft	85,400	...	....	
Homogeneous metal plates, first quality	96,280	...	97,150	Kirkaldy.
Homogeneous metal plates, second quality	72,408	...	73,580	do.
Puddled steel plates...from	102,593	...	85,365	do.
to	71,532	..	67,686	
Puddled steel plates	93,600	..	....	Fairbairn.

TABLE OF THE RESISTANCE OF MATERIALS TO SHEARING AND DISTORTION, in pounds avoirdupois per square inch. (*Rankine*).

Materials.	Resistance to shearing.		Transverse elasticity, or resistance to distortion.
Brass, wire-drawn		...	5,330,000
Copper		...	6,200,000
Iron, cast	27,700	...	2,850,000
„ wrought	50,000	...	8,500,000 to 9,500,000
Fir: red pine	500 to 800	...	62,000 to 116,000
„ spruce	600	...	....
„ larch	970 to 1,700	...	....
Oak	2,300	...	82,000
Ash and elm	1,400	...	76,000

TABLE OF THE RESISTANCE OF MATERIALS TO STRETCHING AND TEARING BY A DIRECT PULL, in pounds avoirdupois, per square inch. (*Rankine.*)

Materials.	Tenacity, or resistance to tearing.		Modulus of elasticity, or resistance to stretching.
Brass, cast	18,000	...	9,170,000
„ wire	49,000	...	14,230,000
Copper, cast	19,000	...	
„ sheet	30,000	...	
„ bolts	36,000	...	
„ wire	60,000	...	
Iron, cast, various qualities	13,400 to 29,000	...	14,000,000 to 22,900,000
„ average	16,500	...	17,000,000
Iron, wrought, plates	51,000	...	
„ joints, double rivetted	35,700	...	
„ „ single rivetted	28,600	...	
„ bars and bolts	60,000 to 70,000	...	29,000,000
„ hoop, best-best	64,000	...	
„ wire	70,000 to 100,000	...	25,300,000
„ wire ropes	90,000	...	15,000,000
Steel bars	100,000 to 130,000	...	29,000,000 to 42,000,000
Steel plates, average	80,000	...	

RESILIENCE OF IRON AND STEEL. (*Rankine.*)

Metal under tension.	Ultimate tenacity.	Working tenacity.	Modulus of elasticity.	Modulus of resilience.
Cast-iron, weak	13,400	4,467	14,000,000	1·425
„ average	16,500	5,500	17,000,000	1·78
„ strong	29,000	9,667	22,900,000	4·08
Bar iron, good average	60,000	20,000	29,000,000	13·79
Plate iron „	50,000	16,667	24,000,000?	11·57?
Iron wire „	90,000	30,000	25,300,000	35·55
Steel, soft	90,000	30,000	29,000,000	31·03
„ hard	132,000	44,000	42,000,000	46·10

NOTE.—In the above table of resilience, the working tenacity is for a "dead" or steady load. The modulus of resilience is calculated by dividing the square of that working tenacity by the modulus of elasticity.

TABLE OF THE RESISTANCE OF MATERIALS TO BREAKING ACROSS, in pounds avoirdupois per square inch. (*Rankine.*)

NOTE.—The modulus of rupture is eighteen times the load which is required to break a bar of one inch square, supported at two points one foot apart, and loaded in the middle between the points of support.

Materials.	Resistance to breaking, or modulus of rupture.
Sandstone	1,100 to 2,360
Slate	5,000
Iron, cast, open-work beams, average	17,000
„ solid rectangular bars, various qualities	33,000 to 43 500
„ „ „ „ „ average	40,000
„ wrought, plate beams	42,000
Ash	12,000 to 14,000
Beech	9,000 to 12,000
Birch	11,700
Elm	6,000 to 9,700
Fir: red pine	7,100 to 9,540
„ spruce	9,900 to 12,300
„ larch	5,000 to 10,000
Lancewood	17,350
Lignum-vitæ	12,000
Oak, British and Russian	10,000 to 13,600
„ Dantzic	8,700
„ American red	10,600
Sycamore	9,600
Teak, Indian	12,000 to 19,000

TABLE OF THE RESISTANCE OF MATERIALS TO CRUSHING BY A DIRECT THRUST, in pounds avoirdupois per square inch. (*Rankine.*)

Materials.			Resistance to crushing.
Brick, weak red			550 to 800
„ strong red			1,100
„ fire			1,700
Chalk			330
Granite			5,500 to 11,000
Limestone, marble			5,500
„ granular			4,000 to 4,500
Sandstone, strong			5,500
„ ordinary			3,300 to 4,400
„ weak			2,200
(Rubble masonry, about four-tenths of cut stone).			
Brass, cast			10,300
Iron, cast, various qualities			82,000 to 145,000
„ „ average			112,000
„ wrought			about 36,000 to 40,000
Ash	crushed along the grain		9,000
Beech	„	„	9,360
Birch	„	„	6,400
Box	„	„	10,300
Elm	„	„	10,300
Fir: red pine	„	„	5,375 to 6,200
„ American yellow pine	„	„	5,400
„ larch	„	„	5,750
Lignum-vitæ	„	„	9,900
Mahogany	„	„	8,200
Oak, British	„	„	10,000
„ Dantzic	„	„	7,700
„ American red	„	„	6,000
Teak, Indian	„	„	12,000

NOTE.—The resistances stated are for *dry* timber. Green timber is much weaker, having sometimes only half the strength of dry timber against crushing.

EFFECTS OF RE-HEATING AND ROLLING (*according to clay*).

Puddled bar	43,904	Tenacity in pounds per square inch lengthwise.
The same iron five times piled, re-heated, and rolled	61,824	
The same iron eleven times piled, re-heated, and rolled	43,904	

CHEMICAL MEMORANDA.

A simple or elementary substance is a body that cannot be resolved or separated into any simpler substances—as oxygen, carbon, iron.

A compound substance is one consisting of two or more constituents—as water, carbonic acid gas, olefiant gas.

The equivalent number or atomic weight expresses the relation that subsists between the different proportions by weight in which substances unite chemically with each other.

The equivalent of a compound is the sum of the equivalents of its constituents.

Specific gravity expresses the difference that subsists between the weights of equal volumes of bodies.

So far as chemists have been able to discover, there are about 65 elementary or simple substances.

No compound body contains all the elementary substances. Most compounds are composed of two, three, or four elements.

TABLE OF ELEMENTARY SUBSTANCES.

Names of Elements	Symbol	Atomic Weight	Names of Elements	Symbol	Atomic Weight
Aluminum	Al	27·4	Nickel	Ni	58·8
Antimony	Sb	122	Niobium	Nb	95
Arsenic	As	75	Nitrogen	N	14
Barium	Ba	137	Osmium	Os	199
Beryllium	Be	9·4	Oxygen	O	16
Bismuth	Bi	210	Palladium	Pd	106·6
Boron	B	11	Phosphorus	P	31
Bromine	Br	80	Platinum	Pt	197·4
Cadmium	Cd	112	Potassium	K	39·1
Calcium	Ca	40	Rhodium	R	104
Carbon	C	12	Rubidium	Rb	85
Cerium	Ce	92	Ruthenium	Ru	104
Chlorine	Cl	35·5	Selenium	Se	79
Chromium	Cr	52·2	Silicium or Silicon	Si	28
Cobalt	Co	58·8	Silver	Ag	108
Copper	Cu	63·4	Sodium	Na	23
Fluorine	F	19	Strontium	Sr	87·6
Gold	Au	197	Sulphur	S	32
Hydrogen	H	1	Tantalum	Ta	182
Indium	In	74	Tellurium	Te	128
Iodine	I	127	Thallium	Tl	204
Iridium	Ir	198	Thorium	Th	231·5
Iron	Fe	56	Tin	Sn	118
Lanthanum	Ln	93	Titanium	Ti	50
Lead	Pb	207	Tungsten	W	184
Lithium	Li	7	Uranium	U	120
Magnesium	Mg	24	Vanadium	V	51·2
Manganese	Mn	55	Yttrium	Y	61·7
Mercury	Hg	200	Zinc	Zn	65
Molybdenum	Mo	96	Zirconium	Zr	89·6

NOMENCLATURE.

The compounds of the non-metallic elements with the metals and with each other, have names ending in "ide" or "uret," as $Fe\,S$, sulphide or sulphuret of iron.

When two or more equivalents of the non-metallic elements enter into combination, the number of equivalents is expressed by prefixes.

Bi means 2 eq., as $N\,O_2$ binoxide of nitrogen.
Ter „ 3 eq., as $Sb_2\,S_3$ tersulphide of antimony.
Penta „ 5 eq.
Sesqui„ $1\frac{1}{2}$ eq. (=2 to 3), as $Fe_2\,O_3$ sesquioxide of iron.
Proto „ first, or 1 to 1, as $Fe\,O$ protoxide of iron.
Sub „ under, as $Cu_2\,O$ suboxide of copper.
Per „ the highest, as $Cl\,O_4$ peroxide of chlorine.

Alkalies neutralise acids, forming salts.

The terminations "ic" and "ous" are used for acids, the former representing a higher state of oxidation than the latter.

When a substance forms more than two acid compounds, the prefixes "hypo" *under*, and "hyper" *above*, are used.

A base is a compound which will chemically combine with an acid.

A salt is a compound of an acid and a base.

When water is in combination with acids or bases, they are said to be hydrated.

LIST OF SOME BINARY COMPOUNDS.

Name of Compound.	Symbol.
Ammonia	$N\,H_3$
Bisulphide of carbon	$C\,S_2$
Carbonic acid gas	$C\,O_2$
Carbonic oxide	$C\,O$
Cyanogen	$N\,C_2$
Hydrochloric acid	$H\,Cl$
Light carburetted hydrogen	$C\,H_4$
Nitric acid	$N\,O_5$
Olefiant gas	$C_2\,H_4$
Peroxide of iron	$Fe_2\,O_3$
Protoxide of iron	$Fe\,O$
Sulphurous acid gas	$S\,O_2$
Sulphuric acid	$H_2\,SO_4$
Sulphuretted hydrogen	$H_2\,S$
Water	$H_2\,O$

COMMON NAMES OF CERTAIN CHEMICAL SUBSTANCES.

Aqua fortis	Nitric acid
Bluestone, or blue vitriol	Sulphate of copper
Calomel	Chloride of mercury
Chloroform	Chloride of formyle
Common salt	Chloride of sodium
Copperas, or green vitriol	Sulphate of iron
Corrosive sublimate	Bichloride of mercury
Dry alum	Sulphate of alumina and potash
Epsom salts	Sulphate of magnesia
Ethiops mineral	Black sulphide of mercury
Galena	Sulphide of lead
Glauber's salts	Sulphide of soda
Iron pyrites	Bisulphide of tin
Jeweller's putty	Oxide of tin
King's yellow	Sulphide of arsenic
Laughing gas	Protoxide of nitrogen
Lime	Oxide of calcium
Lunar caustic	Nitrate of silver
Mosaic gold	Bisulphide of tin
Nitre, or saltpetre	Nitrate of potash
Oil of vitriol	Sulphuric acid
Realgar	Sulphide of arsenic
Red lead	Oxide of lead
Rust of iron	Oxide of iron
Soda	Oxide of sodium
Spirit of hartshorn	Ammonia
Spirit of salt	Hydrochloric acid
Stucco, or plaster of Paris	Sulphate of lime
Sugar of lead	Acetate of lead
Vermilion	Sulphide of mercury
Vinegar	Acetic acid
Volatile Alkali	Ammonia
Water	Oxide of hydrogen
White Vitriol	Sulphate of zinc

TABLE OF THE RELATIVE POWER OF METALS FOR CONDUCTING HEAT.

Gold	1000	Iron	374·3
Silver	973	Zinc	363
Copper	898·2	Tin	303·9
Platinum	381	Lead	179·6

TABLE SHOWING THE NUMBER OF VOLUMES OF VARIOUS GASES WHICH 100 VOLUMES OF WATER, AT 60 DEG. FAHR. AND 30 INCHES BAROMETRIC MEASURE, CAN ABSORB. (Dr. Frankland).

Ammonia	7800 volumes.
Sulphurous acid	3300 „
Sulphuretted hydrogen	253 „
Carbonic acid	100 „
Olefiant gas	12·5 „
Illuminating hydrocarbons	Not determined, but probably more soluble than olefiant gas.
Oxygen	3·7 volumes.
Carbonic acid	1·56 „
Nitrogen	1·56 „
Hydrogen	1·56 „
Light carburetted hydrogen	1·60 „

When water has been saturated with one gas and is exposed to the influence of a second, it usually allows a portion of the first to escape whilst it absorbs an equivalent quantity of the second. In this way, a small portion of a not easily soluble gas can expel a large volume of an easily soluble one.

	Spec. Grav.
Atmospheric air	1·000
Oxygen gas	1·106
Nitrogen gas	0·972
Carbonic acid gas	1·524

TABLE OF THE LINEAL EXPANSION OF METALS PRODUCED BY RAISING THEIR TEMPERATURE FROM 32 deg. to 212 deg. FAHR.

Zinc	1 part in 322	Gold	1 part in 682
Platinum	„ 351	Bismuth	„ 719
Tin (pure)	„ 403	Iron	„ 812
Tin (impure)	„ 500	Antimony	„ 923
Silver	„ 524	Palladium	„ 1000
Copper	„ 531	Platinum	„ 1100
Brass	„ 584	Flint Glass	„ 1248

Expansion of Liquids in Volume from 32deg. to 212deg. Fahr.

1,000 parts of water	become	1,046
„ oil	„	1,080
„ mercury	„	1,018
„ spirits of wine	„	1,110
„ air	„	1,373

CONTENTS.

EXTRACTS FROM TESTIMONIALS.

Dear Sir, *11th October*, 1874.

I have read your work on mines; it is the best work I ever read. and deserves to be circulated in every Colliery district, for the safety of miners. I have had twenty years' practice in the management of Mines.

Swadlincote Colliery. Yours, &c., JOSEPH EAMES.

Sir, *January*, 1866.

I worked at Mr. Ackroyd's Colliery when you had the management. I found you a man both in knowledge and principle. I am in a situation as underground Viewer, but deficient of knowledge in many things. I ask help, knowing there is no one more able than you to give it. I had two men from home (England), with two copies of your work, but they would not sell one at any price. Send me a copy if possible. I will also forward you money for instruments to survey and plan with; be kind enough to purchase suitable ones for me.

Gowerie Mines, Cow Bay, Cape Breton, British North America. CHARLES INMAN.

Sir, *15th December*, 1864.

I have read your "Conversation on Mines." I must confess I have learnt many things I never knew before, for which I desire to return my humble thanks for the instructions received. HENRY LOWERY.

Deputy at Rainton Colliery, Durham.

The Colliery Guardian—*20th August*, 1864.

A Conversation on Mines, &c, between Father and Son, by William Hopton, Colliery Manager, St. Helens, Lancashire.—This is an excellent little book, designed especially for the instruction of working miners, by one who is well acquainted with their wants, and evidently knows how to supply them. We cordially commend this little manual to the subordinate officers in collieries, and indeed to every working miner. Let them purchase it, and employ their leisure in mastering its contents, and they will find that both the money and the time have been well spent. Such a work, well understood by every miner, would do more to prevent colliery accidents than any army of inspectors, and to raise the collier in the social scale than all the efforts of unions and all the vague declamations of delegates.

Mining Journal Office— *18th July*, 1864.

PRACTICAL COLLIERY WORKINGS—Under the title of "A Conversation on Mines between a Father and Son," Mr. William Hopton, Colliery Manager, St. Helens, Lancashire, has issued a neat little volume, the object of which is to provide a work for practical colliers, written in a style which can be readily understood by them.

Mr. Hopton begins with supplying the elements of those natural laws upon which the safe working of collieries depends, and gradually leads the reader on until not only good methods of laying out and ventilating collieries are thoroughly understood, but until the dialling of a mine and the preparation of the plan can be undertaken with the utmost confidence. The book is one which cannot fail to be well received by all connected with collieries, and at the same time, it reflects great credit upon the author.

St. Woolos Road, Newport—*July 18th*, 1864.

To Mr. J. J. Campbell,

Sir,—I beg to acknowledge having received the Treatise on Mining by Mr. Hopton, for which I am obliged; and beg to say, as a practical man for a great number of years, that it is the best work of the sort I have seen for the class of men it is intended for; and shall have great pleasure in recommending it to all who may require a knowledge of the subject. Yours truly, CHRISTOPHER FIRBANK.

P.S.—I will strongly recommend the work. C.F.

Dear Sir,—I am an under-viewer, and have had upwards of twenty years' experience. I find it a very valuable little work for me, and worth the notice of experienced men, and no doubt Mr. Hopton is a man thoroughly up to the mark.

I am, yours respectfully, JOHN TRUMAN.

Swadlincote Old Colliery, near Burton-on-Trent,
27th July, 1864.